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EDITORIAL.

ITEMS AND NOVELTIES.

Machine for Testing the Value of Lubricants.—We give herewith an engraving of a machine for testing the value of lubricants by determining their power of reducing friction, resisting pressure, sustaining high temperatures, and cooling heated journals. The machine was invented by Professor R. H. Thurston, of the Stevens Institute of Technology, Hoboken, N. J., and the particular form shown in the illustration was designed by Mr. J. A. Henderson, a student in that institution.

The machine is intended to give the co-efficient of friction, pressure on bearing, and temperature of journal boxes at any time, and the readings are proposed to be taken at short intervals throughout the test.

The machine consists of a shaft, A, running in two bearings, B B, and driven by a pulley, C. The shaft is supported by a standard, D D, carried on the base, E E. At the outer end of the shaft is a journal, F, of either steel or selected iron; suspended from this journal, and clamping it by means of boxes, G G, is an arm, H H, carrying an adjustable weight, I, which may be changed for one of different size, or adjusted on the arm, as is found requisite.

The pressure under which the oil is to be tested is obtained by setting up the boxes, G G, by means of the screw K acting on the nut L, on which nut the spring J rests. The *pressure per square inch* is read off from the scale N N, which is traversed by an index, M, attached to the spring J. The friction causes the arm H H to swing out from the vertical position, the *moment of friction* being indicated by the index on the arm O, which traverses the graduated arc P P. The *co-efficient of friction* is obtained by dividing the reading on the scale cut on the arc P P, by a second set of empirical divisors laid off on the scale N N. The temperature is indicated at all times by a thermometer, Q Q, set in the upper brass.

In using the machine, a small and determinate quantity of the oil to be tested is placed on the journal F, and the pressure being adjusted by the screw K to that at which the oil is desired to run under test, the machine is started at a speed which will give the desired relative velocity of rubbing surfaces. Observations are made at short intervals, and recorded, until the test is closed by rapid heating, as shown by the thermometer, and excessive increase of friction, as indicated by the arm H H swinging up against its chocks. Competing oils are similarly tried, and the records afford a perfect means of comparison.

Thus, sewing-machine builders desire oil of long endurance and small frictional resistance and viscosity; on locomotives an oil that will bear high pressure for the greatest length of time without heating is the most desirable, even although not as limpid and of as slight frictional resistance. The relative power of resisting high temperatures without decomposition is another important point which may be tested.

Any lubricant may be tested, whether mineral, vegetable or animal oil, tallow or mixture like axle grease.

The only precautions necessary are not to allow the temperature to run so high as to injure the thermometer or the journal surface, and to measure accurately the quantity of oil used.

The form shown in the cut is that proposed for general use, but for extremely heavy pressures another form has been designed, in which the pressure on the journal is obtained by a clamp composed of a fixed arm and a spring, the spring being set up by a hand-wheel turning a nut in the end of the fixed arm. In this form of the machine, the moment of friction is measured by the compression of the spring. The essential feature of both forms is the combination in one machine of apparatus for making simultaneous dynamometrical and thermometrical tests of the lubricant.

Fig. 1

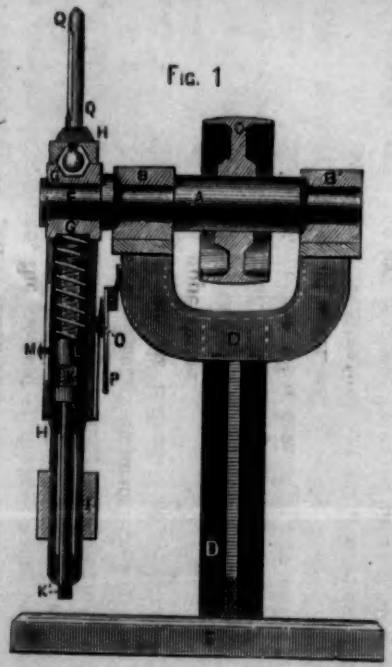
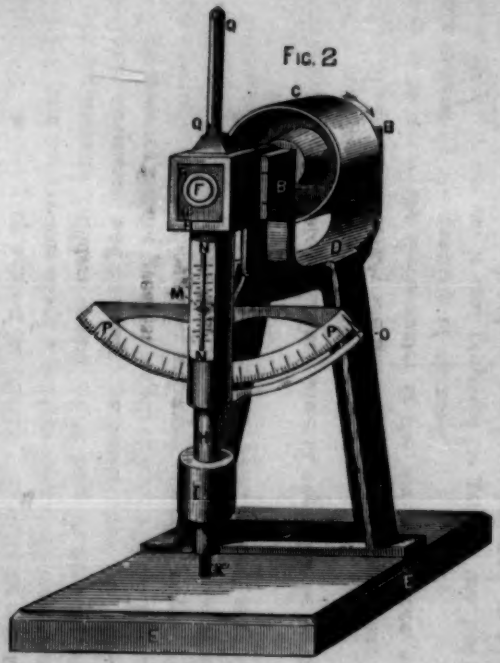


Fig. 2



MACHINE FOR TESTING THE VALUE OF LUBRICANTS.

metrical tests of the lubricant.

The machine is patented by Professor Thurston, but the patentee announces that master mechanics can obtain permission to construct and use it on application to him. He will also furnish applicants with the necessary dimensions for the machines and with the numbers to be attached to them.*

Ingenious Engineering.—The *Chronique de l'Industrie* records a very ingenious piece of engineering, which is worthy of placing on record. During the construction of the bridge at Kuilenborg, Holland, one of the principal traverses, some 465 feet in length, was placed about one inch too far on the piles. This error, upon discovery, was rectified in the following manner:

The expansion of the mass of metal was ·0394 inches per Fahrenheit degree. At the locality of the work the difference between the temperature of the air by day and by night was 25° Fahr. In the morning the too far advanced end of the traverse was securely bolted down, when during the day the heat of the sun expanded the metal so that the free end advanced ·985 of an inch; then at night the other extremity was fastened down, and the contraction caused an equivalent movement of this end. By several operations of this kind the traverse was brought into proper position.

Consumption of Timber.—But few people are aware of the fearful drain which the railroads make upon the timber resources of the country, and a proper appreciation of this fact might lead speedily to the substitution of some cheap and practical material for the wooden tie now so universally employed.

The estimate is made upon good authority that the number of railroad ties at present in use is 150,000,000, and as young timber is mainly employed, a cut of 200 ties to the acre is above, rather than under, the average, and it has therefore required the product of 750,000 acres of well timbered land to furnish this supply.

As railroad ties have a life of about five years, about 30,000,000 ties are required annually for repairs—a supply which demands annually the product of 150,000 acres.

The manufacture of rolling stock requires annually the product of 350,000 acres more, from which data it appears that the railroads are depleting the woodland of the country at the rate of 500,000 acres per year—a demand which is also rapidly on the increase.

* Railroad Gazette, May 17, 1873.

Growth of American Iron Industry.—The following table, from the compilation of the American Iron and Steel Association, exhibits in very concise form the growth of the home production, importation and consumption of rails in the United States from 1849 to 1872, inclusive, together with the growth of the American railway system during the same period.

YEAR.	Total rails made in the U. S.—Tons of 2,000 lbs.	Total rails imported.——Tons of 2000 lbs.	Total consumption of iron and steel rails.	Miles of Railroad built in the U. S. in each year.
1849	24,318	69,163	93,481	1,369
1850	44,083	159,080	203,163	1,656
1851	50,603	226,350	276,953	1,961
1852	62,478	294,750	357,228	1,926
1853	87,864	358,794	446,658	2,452
1854	108,016	339,439	447,455	1,360
1855	138,674	153,019	291,693	1,654
1856	180,018	186,594	366,612	3,643
1857	161,918	215,166	377,084	2,491
1858	163,712	90,894	254,606	2,460
1859	195,454	83,958	279,412	1,821
1860	2050,38	146,610	351,648	1,846
1861	187,818	89,388	277,206	621
1862	213,912	10,186	224,098	864
1863	275,768	20,506	296,274	1,050
1864	385,369	142,457	447,826	738
1865	356,292	63,327	419,619	1,277
1866	430,778	117,878	548,656	1,832
1867	462,108	184,840	646,948	2,227
1868	506,714	300,160	806,874	3,033
1869	593,586	336,500	930,086	4,977
1870	620,000	472,403	1,092,403	6,145
1871	775,733	566,202	1,341,935	7,453
1872	941,992	530,850	1,471,842	6,043

A Japanese Suspension Bridge.—The statement is made that Mr. T. J. Waters, the surveyor general of the Japanese government, has lately completed the first suspension bridge in Japan. It is constructed over a ravine, filled with water, which separates the Mikado's palace from the pleasure garden, and is intended solely for the use of the Imperial household and attendants. According to the account of the structure, published in the Japan Weekly Mail, it appears to be 234 feet long, 17 feet wide, and 60 feet above the water. It is supported by two red brick columns, 64 feet high from the foundation,

and the cables are of galvanized iron. The hand-rails are of thin wire rope, and, with the entire structure, are handsomely ornamented. The anchors are buried 23 feet deep, and the bridge has been tested with a rolling load of 20 tons.

American Rails.—The "Bulletin of the American Iron and Steel Association" lately contained some interesting statistics relative to the production of rails in the United States, from which it appears that the total number of net tons of rail reported for the year 1872 amounted to 941,992.

The production of each State, as well as the arranged table for comparing the same with that of 1871, is herewith submitted:

State.	1872.	1871.
Pennsylvania,	419,529	335,624
Ohio,	121,923	75,782
Illinois,	106,916	91,178
New York,	82,457	87,022
Wisconsin,	37,284	28,774
Massachusetts,	29,242	28,864
Maryland,	26,472	44,941
Indiana,	23,893	12,778
W. Virginia,	20,100	5,000
Missouri,	15,500	8,200
Mississippi,	14,620	9,667
Maine,	14,058	13,383
Michigan,	9,883	14,000
New Jersey,	9,185	6,700
Georgia,	6,930	7,840
Kentucky,	4,000	6,000
	941,992	775,733

The Woolwich Steam Hammer.*—The Woolwich workmen have lately been getting into place the great plate upon which is to rest the anvil block of the new thirty-five ton steam hammer. This plate weighs of itself one hundred and three tons, and had to be cast, of necessity, in an open mould. The surface which is to receive the anvil block lay, therefore, downward; and when, after many weeks, the colossal casting grew cool, it was needful to turn the huge mass

* Eng. and Mining Journal.

completely over. On April 17th, an army of sturdy smiths undertook this task with hydraulic jacks, and a combination of the strongest tackle. Before night they had lifted the monstrous lump of solid metal, twenty-two feet square, and since then they have laid it in its bed, upon the rock-like structure of cement and piles made to receive it. The anvil block to be mounted on the huge plate, will weigh only a trifle short of 200 tons; and the steam-hammer which will strike upon it, is made of thirty-five tons of metal. The whole weight of metal in the hammer is about 500 tons.

Coal in Russia.—Referring to this subject, one of our exchanges* states that an important advantage which Russia possesses, to which, however, it appears the inhabitants are not yet sufficiently alive, is the existence within their borders of an abundance of mineral fuel. As yet, however, notwithstanding the fine field for the development of the production of coal in Russia, scarcely any steps have been taken in this direction.

One magnificent deposit of unusually fine black gas coal is mentioned as especially valuable, occurring near the River Kama. It is stated to be thick near the surface, easily worked, and easily transported to the river side, but at present lying unutilized for want of proper enterprise.

Brown coal exists, according to our authority, in the central districts, large deposits of anthracite in the south, and immense beds in the basin of the Donetz, all of which await only the enterprise which shall dig it from its bed, and utilize it in the manufacture of its companion world-civilizer—iron.

English Railroad Statistics.—The very reliable compilation of the Board of Trade for 1871, shows that at the close of that year there were in the United Kingdom 15,376 miles of railroad, 123 miles having been constructed during the year. The average cost per mile had been £35,943 or about $180,000 gold. These roads earned an average of £3,063 or $15,300 per mile, of which earnings 44 per cent. was from passenger traffic and 56 per cent. from freight, and the average working expenses were about 48·4 per cent of the gross receipts. The average income earned on the capital invested was 4·43 per cent.

* Iron.

The Incrustation of Boilers.—One of the papers read before the Master Mechanics' Association, which lately met in Baltimore, was the report of the committee on the operation and management of locomotive boilers, including the purification of water. The report, amongst several other recommendations, suggests for locomotives the remedy of employing rain water. The committee make a calculation to show that the collection and storage of rain water is practicable. In Missouri, for example, the annual rainfall is forty-one (41) inches. A reservoir covering one acre, and having a depth of sixteen to eighteen feet, with a roof or collecting surface of four acres, would receive 4,573,810 gallons of water per year. On a section of 100 miles of railroad, five of these reservoirs, located at intervals of twenty miles, would receive annually 22,869,000 gallons. A locomotive that does an average year's work (31,200 miles), consumes about 1,039,500 gallons of water, so that if the tonnage over the section necessitates the use of twenty engines, the five reservoirs would contain more than enough to supply them. The committee expressed the opinion that in the course of time, the saving in repairs to boilers would repay the amount expended in the construction of such reservoirs. The estimate being based upon the statement that the annual cost of repairs to a locomotive, made necessary by the use of impure water, is about $750.

Government Aid to Science.—It is gratifying to be able to notice that the Government has wisely responded to the urgent solicitations of engineers and the engineering press throughout the country in appropriating $100,000 for the purpose of continuing the experimental investigations upon steam boiler explosions, commenced by the Franklin Institute in 1835, and very ably extended by Col. Stephens, in the highly instructive experimental explosions during the last year at Sandy Hook. The experiments authorized by this very liberal appropriation will be made in part at Sandy Hook, and in part at Pittsburg or Cincinnati—each being under the charge of a committee of five engineers. The information which may thus be obtained may prove of inestimable public benefit, and we shall look forward to the inauguration of the experiment with great interest.

Coming Industrial Exhibitions.—It appears that the interest attaching to the eminently useful plan of systematically arranging, for display and inspection, objects of art and manufacturing industry, is growing with each year, and in no country does it seem to have obtained such unbounded popularity as in our own. The following

summary of present and prospective exhibitions will give an idea of the interest centering in them.

Leaving out of consideration the colossal display which is at present attracting the eyes of the world to Vienna, we find at home that the American Institute proposes to open its yearly exhibition at the building on Third avenue, between 63d and 64th streets, in New York City, on the 10th of September next, of which the management have taken the precaution to give timely notice to those wishing to participate as exhibitors.

The city of Cincinnati proposes to repeat this year the very successful exhibitions held for three successive years under the auspices of its several trade associations and the Ohio Mechanics' Institute, the time for the opening of which is announced for the 3d of September next.

The cities of Louisville and Newark are to be placed in the list with a similar intention, while from Chicago comes the announcement that, to properly commemorate the second anniversary of the historic calamity which recently befel her, no less than to indicate to the world the wonderful recuperative power which has already effaced the traces of this misfortune, a grand inter-State exposition is proposed. The date for the opening of this exhibition is stated to be fixed for the 1st of September, the work of erecting buildings necessary for the purpose being already in hand.

Artificial Magnets.—M. Jamin recently exhibited a magnet constructed by himself, which carried upward of twenty-two times its own weight. The magnet in question weighs two kilogrammes, and supports forty-five kilogrammes. The usual carrying capacity of artificial magnets is less than three or four times their own weight; though there have been isolated instances in which much greater power has been obtained. It is worthy to notice that M. Jamin has followed to its limit the plan of employing a number of plates—which is commonly followed where a strong magnet is wished. The only variation in his method from that usually employed seems to be in the fact that, instead of employing in his composite bar a number of thick plates, he has used a great number of very thin plates, superposed—each very thoroughly magnetized.

Hydrofluoric Acid.—Mr. A. P. Stuart gives the following hint which may prove of value to those who have occasion to make frequent use of this reagent in their laboratory work. It is well-known that in the production of this acid by the action of sulphuric acid on

fluorspar, there remains behind in the platinum or lead retorts an extremely hard compound, which cannot be removed without great difficulty.

According to the author, this disagreeable consequence can be obviated by employing, instead of fluorspar, a mixture of equal parts of fluorspar and gypsum. The residue, in this case, left behind in the retort, may be readily removed upon the application of water.

A New Polishing Agent.—Dr. Elsner states that the accidental use in his household of the water which had been employed to boil potatoes for cleansing silverware, led to the unexpected result that this was much superior in its cleansing action to the polishing powders so generally employed. It was found that by simply rubbing the article with the fine deposit of potato flour, that it took on an excellent polish, without the disagreeable necessity of subsequently using the brush to remove the material, as it is necessary where powders are employed instead.

Fluorine and Sodium for Cold Short Pig.—An experiment in removing phosphorus from iron during the puddling process by treatment with a small percentage of fluorspar in the puddling furnace, is announced as having been eminently successful at the iron works at Thale in the Hartz. The difference of opinion amongst metallurgists, concerning the efficiency of "medicines" of any kind, are well known; but any well-authenticated results which have been obtained with their employment, warrant careful attention. In the case here referred to, the pig iron used in the conversion was of the brand known as Ilseder, which ranks with the worst of the German irons, in virtue of its notable percentage of sulphur and phosphorus.

The iron in question was puddled along with about 1½ per cent. of fluorspar, and the product is claimed to have been a fibrous iron, which, when rolled, did not exhibit the slightest trace of cold-shortness.

Apropos of the same subject, a small application of sodium has been suggested by MM. Girard and Toulaire, who propose to conduct the vapors of sodium or potassium into molten pig iron, and then decomposing the alloy thus obtained by means of a blast of air. It has been declared by Springmühl that, by addition of sodium to molten iron in a crucible, and lixiviation of the product in water, a very pure and soft iron may be obtained, which, on second melting, loses its porosity.

It has been stated by experts that in the event of any large demand ensuing for sodium, it can be prepared in quantity at a cost but little, if at all, greater than that of zinc.

The Coming Transit of Venus.—The following is the description given of M. Janssen's method of photographing the apparent contacts of Venus with the sun's edge. The sensitive plate of the apparatus is in the form of a disc, fixed upon a plane which rotates upon an axis parallel to that of the telescope. The disc is eccentric, so that the images are formed near its circumference. Before it, a second disc, forming a screen, is arranged, in which is made a small aperture in order to limit the photographic impression of the portion of the solar image, to around the locality where the contact takes place. The circular plate which carries the sensitized plate is toothed and placed in communication with a small escapement apparatus, actuated by an electric current.

At each second the pendulum of the clock interrupts the current, the plate turns ahead one tooth, and thus exposes a fresh portion of the plate to receive an impression. If, therefore, the disc has 180 teeth the plate will receive 180 images of the solar edge. The photographic work can thus be begun a minute and a half before the presumed instant of contact; then when the series relating to the first contact is obtained, the sensitive plate is withdrawn and another substituted, which gives the second contact, and so on for the four.

Testing for Sulphur.—In the German Chemical Society's *Berichte*, Mr. B. Tollens calls attention to an important omission in the text-books and guides for chemical analysis, concerning a precaution which it is necessary to observe in testing for the presence of sulphur.

The simplest process, and the one universally followed, to detect its presence qualitatively, consists in bringing the test specimen, mixed with soda, upon charcoal, and heating the same in the reducing portion of a blowpipe flame.

The omission to which the author calls attention in a brief notice, and which may often lead beginners astray, lies in the fact that it is nowhere stated that the gas flame cannot be employed for this purpose, but only the flame of an oil lamp or candle, since the gas flame of itself contains invariably so much sulphur, that by directing it upon pure soda for a minute the resulting mass will perceptibly blacken silver.

A Chemical Experiment.—To prove that the inner, dark portion of an illuminating flame contains combustible gases, the general practice with experimenters is to insert into that part of the flame a glass tube, so inclined that a portion of these gases shall rise into it, and thereupon igniting them at the farther extremity of the tube, or leading the contents of the tube by an aspirator into a convenient vessel, when its combustibility can then be directly tested. Mr. Heuman has communicated to the German Chemical Society another method, and a simpler one, of accomplishing the result, which seems worthy of notice.

He recommends taking advantage of the well-known fact that a mixture of about 4 parts of chlorate of potassa and 1 part of strontium nitrate, heated to fusion, will burn with a very intense flame in hydrogen or illuminating gas, when once the ignition of the oxygen liberated from this mixture is effected by contact with a flame.

To perform this very pretty experiment, the author states that it is only necessary to fuse a small quantity of the mixture in question in a little spoon at the apex of a luminous gas flame, and then to lower it into the dark portion, when a brilliant combustion will immediately ensue; while, when removed to the luminous portion of the flame, or taken altogether out of it, it is at once extinguished.

The Intra-Mercurial Planet.—Mention was made in a late number of the "Journal" of the observation of Mr. Cowie, at Shanghai, in China, of the passage across the sun's disc of a peculiar object, which he infers to have really marked the transit of a planet nearer to the sun than Mercury, the existence of one or several of which have for some time been suspected by certain astronomers. Similar observations to that of Mr. Cowie have been previously made and a similar inference drawn from them by several observers, though none of the reputed discoveries have been regarded as sufficiently convincing to establish the fact.

It will probably require either that the planet or planets shall be actually seen during a solar eclipse, or that the existence and transit of the same shall be demonstrated and predicted from mathematical calculation, based upon perturbations of its neighboring planets, or other data, before the evidence shall be deemed sufficiently conclusive.

It is, however, interesting to note the fact that Prof. Daniel Kirkwood has taken the observation of Mr. Cowie and, employing it in conjunction with the recorded dates of similar phenomena, has arrived at the conclusion that they indicate the existence of an interior planet

in close proximity to the sun, whose year, or time of revolution, is 34 days, 22 hours and 32 minutes.

Editorial Correspondence.

Editor of Journal of Franklin Institute:

My dear Sir,—As you are recording novelties in the "Journal," I take the liberty to send to you a plan for the attachment of the small mirrors upon the tuning-forks to be used in projecting Lissajou's curves. With the forks made by König it is hardly possible to get a projection of the curves more than six or eight inches square, especially if a lens is used to focus the beam of light. While making a pair of these forks for demonstration in the lecture-room, I stumbled upon a result that surprised me, and in every way proves itself superior for such a purpose to the common method of attaching the mirrors to the forks, viz., by screwing them into the fork.

As I have no convenience for drilling iron, I tried to fasten the round glass mirror to the fork with the cement known as marine glue. While using the forks thus fixed, one of the mirrors accidentally was struck and loosened, when the line, that before had been but a foot long upon the screen, suddenly spread out to *ten feet*. The glue was a little elastic and permitted the mirror to have an angular motion of its own. I took the hint, and mounted each fork with the glass, separated from it by a strip of india-rubber, so as to allow an angular motion in the same plane as the vibration of the fork, and the elasticity of the rubber can be utilized so as to give an angular motion many times greater than that of the forks. So fixed, I can easily get a band of light eight or ten feet long, or twice that if both forks vibrate in the same plane, while figures resulting from the combined movements at right angles are magnificent and, I think, unparalelled.

This great size does away with the necessity for a lens, and if sunlight is used reflected from a porte lumiere, and passed through a small hole in a card but three or four inches from the first fork, there will be no lack of definition. All the smaller ratios, as $\frac{1}{1}$, $\frac{2}{1}$, $\frac{3}{2}$, $\frac{4}{1}$, &c., can be seen and *counted* by an audience of a thousand. And, more, a pair of such forks, with everything necessary for such an exhibition, can be made for ten dollars.

A. E. Dolbear.

Physical Laboratory, Bethany College, W. Va.

A GEOMETRICAL SOLUTION OF SOME ELECTRICAL PROBLEMS.

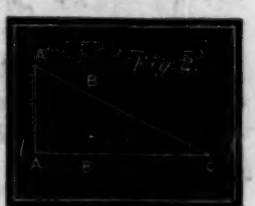
By Prof. Edward C. Pickering.

The analytical solution of the following problems is always a little complex, considering the simplicity of the results, and therefore unsatisfactory to the student. It is hoped that the following geometrical method may prove both useful for purposes of instruction, and suggestive of a simple solution of other more difficult problems.

The method employed is to represent by horizontal distances or abscissas, electrical resistances, and by ordinates the potentials of the various parts of an electrical circuit. Thus in fig. 1, neglecting the lines to the left of AA′, suppose AC equals the total resistance of the circuit, and that the battery has a potential AA′. If, then, one pole is connected with A, and the other with the ground at C, the potential of any point B may be found by drawing the straight line A′C, and erecting the perpendicular BB′.

Wheatstone's Bridge.—Four resistances, M, N, O and P, are connected together, end to end, two opposite junctions being connected with the poles of a battery, and the other two with a galvanometer. The needle of the latter will not be deflected when M : N=P : O. To prove this, lay off fig. 1, AB=M, BC=N, ED=O and DA=P. Suppose the battery connected at A, erect the perpendicular AA′ equal to its potential, and draw the lines AC and AE. Draw also the lines BB′ and DD′. They will represent the potentials at the terminals of the galvanometer, and will be equal if no current passes. But AA′ : BB′=M+N : N and AA′ : DD′=P+O : O, and if BB′=DD′, M+N : N=P+O : O, hence M : N=P : O.

II. *Poggendorff's Method of Measuring Potentials.*—Let E′ equal the potential of the battery to be tested, and E the potential of that with which it is to be compared, and which is taken as a standard. The galvanometer is connected with the latter battery, interposing a resistance to reduce the current. Now connect the two terminals of the other battery with the galvanometer, so as to pass a current through it in the opposite direction, and vary the interposed resistance until the needle comes to zero. Call G the resistance of the galvanometer, and R that of the standard battery and resistance; then there will be equilibrium when E : E′=G+R : G. To



prove this, let AA′, fig. 2, equal E, AB = R, and BC = G. Let DD′ also equal E′. For equilibrium DD′ must be equal and opposite to BB′. But AA′ : BB′=AC : BC or E : E′=G+R : G.

III. *Thomson's Method of Measuring the Resistance of a Battery.*—This method, although much more recent than the others, is scarcely of less importance. The galvanometer is connected with the battery, and a resistance R interposed, to reduce the deflection. R is then removed and the galvanometer shunted, until precisely the same deflection is again produced. Call B the resistance of the battery, R′ that of the shunt, and G that of the galvanometer. Then B $=\frac{RR'}{G}$. In fig. 3, let AA′ equal the potential of the battery, AB=B, BD=R, DE=G. The current passing through the galvanometer will then in the first case be measured by DD′. When the galvanometer is shunted its resistance is reduced $\frac{GR'}{G+R'}$. Lay off BC equal to this quantity. The current in the second case evidently equals BB′, and since the deflection is the same in both cases, we must have DD′=BB′.

Now AA′—DD′ : DD′=B+R : G and AA′—BB′ : BB′=B : $\frac{GR'}{G+R'}$.

Hence B + R : G = B : $\frac{GR'}{G+R'}$, or GB (G+R′)=GR′ (B+R), G²B+GBR′=GBR′+GRR′ and GB=RR′. Hence B=$\frac{RR'}{G}$.

In the same way the deflection which will be produced in any given case may be determined, or the resistance which should be inserted to render it a maximum. The many applications of this method are, however, so obvious that further illustration seems unnecessary.

May 13th, 1873.

Franklin Institute.

Proceedings of the Stated Meeting March 19, 1873.

The meeting was called to order at the usual hour, with the President, Mr. Coleman Sellers, in the chair.

The minutes of the last meeting were read and approved.

The Actuary submitted the minutes of the Board of Managers, and reported that at the stated meeting held March 12th, 1873, the following donations had been received into the Library:

Zones of Stars observed with the Meridon Transit Instrument, at the U. S. Naval Observatory. From the Superintendent.

Zones of Stars observed at the U. S. Naval Observatory with the Mural Circle. From the Superintendent.

The Nineteenth Annual Report of the Chief Engineer of the Cincinati Fire Department. From the Chief Engineer.

Second Annual Report of the Board of Commissioners of the Department of Public Parks, New York City. From the Board.

Report of the Inspector of Buildings of Boston, Mass. From the Inspector.

Thirty-fourth Annual Report of the Boston Fire Department. From the Chief Engineer.

Annual Report of the Chief Engineer of the Water Department of the City of Philadelphia, for the year 1872. From the Chief Engineer.

Report of the Board of Public Charities of the State of Pennsylvania, 1872. From the Board.

Report of the Proceedings of the Meteorological Conference at Leipsic. From the Meteorological Committee.

Monthly Notices of the Royal Astronomical Society, January, 1873. From the Society.

The reports of the several standing committees were presented and accepted.

The several special committees reported progress and were continued.

The President next announced the paper for the evening to be upon the Horse-Power of Steam Boilers, by William B. Le Van. The same is published in the Journal of the Institute for June, 1873.

The Secretary then read his monthly report on Novelties in Science and the Mechanic Arts.

The President presented to the notice of the members a reading table, manufactured by the students of the Worcester Free Institute of Industrial Science, and made some remarks concerning the history, plan and present condition of the school, and upon the bearing of this and similar modes of training upon the character of the mechanics. The President's remarks are published in the Journal of the Institute for April, 1873.

Under the head of new business, the President announced the

names of the following gentlemen as members of the Committee to fix a factor of safety in carrying steam pressure, in obedience to resolution offered at the February meeting of the Institute: Mr. Robert Briggs, Chairman; Messrs. Wm. B. LeVan, J. H. Cooper, L. Schütle and W. F. Durfee.

Mr. Bartol offered the following preamble and resolutions:

Whereas, The use in lamps of the various lighter products of petroleum or coal oil results in an alarming number of deaths and conflagrations, which disastrous results are rapidly on the increase; and, *whereas*, from the experiments of our worthy Secretary, it appears that less than one per cent. of the various oils or illuminating compounds sold in this city are fit for use in lamps; be it

Resolved, By the Franklin Institute of the State of Pennsylvania, that it earnestly recommends and petitions the Legislature of the State to pass an act or acts embodying the following points: To appoint a competent commission to investigate and determine some satisfactory test whereby it can be ascertained which oils or compounds are safe to be used in lamps and which are unsafe. To make it a penal offence to manufacture, compound, sell or knowingly use any oil or compound that will not stand the required test, and that in case of death resulting from the same, the guilty person or persons shall be liable to conviction for manslaughter. And further be it

Resolved, That the Secretary be and is hereby instructed to furnish a copy of these resolutions to the Speaker of each House, and to the Governor of the State.

The resolution was carried.

Mr. William B. LeVan moved the following:

Resolved, That the Publishers of the Journal of the Franklin Institute be directed to publish with each number, on the first page, the following:

NOTE.—This society is not responsible, as a body, for the opinion advanced in its publications.

And the mover supported his resolution by remarks upon the subject, which elicited a discussion.

The motion was lost.

Mr. Henry Cartwright, seconded by Mr. J. E. Mitchell, offered the following:

Whereas, An International Exposition of Arts and Manufactures will be held in Vienna in May next, under the auspices of the Austrian Government, and, as in view of our Centennial Exposition in 1876, much valuable information may be gained by a personal inspection of the Vienna display, it is therefore

Resolved, That the proper officers of the Society are requested to appoint one or more of its members as delegates to represent the Franklin Institute at the Vienna Exposition, and that they be requested to report to the Institute on the same.

The resolution was carried, and the meeting thereupon adjourned.

WILLIAM H. WAHL, *Secretary*.

Civil and Mechanical Engineering.

THE CONSTRUCTION OF IRON SHIPS.

By Samuel Holmes.

In the mechanical arst, during the last half century, the forces marshalled by mind have been making great marches in the path of victory. Stronghold after stronghold of the enemy prejudice, has been captured and broken down; yet still the fight continues, and many a whitened warrior may be seen shaking the fragment of his blade and shouting victory, as he lives to witness the obdurate foes of his youth and ripe experience succumb. To sit at the feet of such spirits is to become inspired, and so, rising with firm resolve, many are buckling on the armor of enterprise, and longing, like Alexander, for worlds to conquer.

Were it possible for the eye to take in the iron fleet of the world, the beholder would surely exclaim, "Here must be perfection, if there be truth in the assertion that experience perfects." But how can we reply to the exclamation? Shall we soothe by saying yes, and violate our conscience? No! We look over that vast fleet, and, depite the efforts of one or two earnest mechanical minds, we trace in the multitude of ships a multitude of sins against mechanical arrangement and accuracy.

As we live in an energetic and practical age, the poetry surrounding the wooden ship and the melancholy in her chips is fast dying out, while the noisy chorus of ringing hammers and the clatter of machinery, the servants of the iron age, usurp the place.

It is not our intention to discuss the wooden ship. She only exists because she is cheaper in first cost over her iron rival: so we dismiss her with respect for past services, but disown her for the requirements of the present day, with her solitary, though not lasting advantage.

Iron, strong in itself and so capable of retention of strength in its fastenings, becomes strong in argument through this intrinsic merit; and small as was the iron vessel's beginning, it has gradually grown from the river boat to the ocean mail steamer, and may be found speeding over the main to every clime, reaping the richest profits which are offered to allure the enterprising spirit.

I say iron must uphold a country's marine, because steam is the

world's requirement, and economy the ship owner's. In the first place, the iron ship is lighter, and will, accordingly, carry much more on the same draft and displacement, and has a far greater capacity to stow the increase; secondly, she is stronger, and will endure much more hard work; thirdly, she costs much less for repairs, and has a longer life; and fourthly, she insures at a cheaper rate.

I might continue the enumeration of the advantages of iron over wood, but prefer to support my position by quoting the rapid increase of iron tonnage, which is *the* practical argument, and the one best calculated to give the true position of affairs.

Taking Great Britain as an example, the following table gives the comparison:

	Iron Vessels.		Wooden Ves.		Composite Ves		Remarks.
	No. of Vessels built.	Tons.	No. of Vessels built.	Tons.	No. of Vessels built.	Tons.	
1851	55	15,826	617	133,811			745 per cent. more wood tonnage than iron.
1862	219	106,497	740	115,955			83¼ " " " " " "
1868	309	205,716	378	80,448	4	2,250	155 " " iron " " wood.
1871	510	347,374	502	41,699	10	1,985	733 " " " " " "

From this tabulation it appears that iron tonnage has increased the enormous extent of 2094 per cent. in twenty years, whilst wood tonnage has decreased 68 per cent. during the same period. These figures undoubtedly beat the tattoo of decay and death to wooden ships; an opinion which is substantiated by observing how the poor craft is forced out of the best trades of the shipping world.

Wood had the advantage of lead in the Atlantic trade, but the iron ship has starved her out of competition, the *economy* of the iron vessel being unqestionably the cause of this rapid development.

To discuss this important shipping question in its relations to American interests, we must know positively where the obstruction to American shipping lies, in order to attack the evil with certainty and success. A pamphlet, issued a short time since, entitled "Ship-building and Ship-owning by Americans in Connection with Foreign Trade," emanating, I believe, from a leading Philadelphia firm of ship owners, traces the disadvantageous position in which Americans are at present placed to three causes:

First, "The risks arising during the late war;" second, "The

substitution of iron for wooden vessels;" and third, "The cheaper cost of building iron vessels elsewhere than in America, together with the larger credits which the heavy capital of foreign builders enables them to accord to purchasers." The pamphlet then proceeds to state, "the problem to be solved is, how best to neutralize the third cause," and I am happy to know it is in my power to suggest and develop a plan to aid the solution of this problem. With one more quotation from the above named pamphlet I pass on.

It states, "It is plain that an unaided owner cannot employ American ships unless their *cost is reduced.* It is equally plain that of the various elements of cost, builders cannot seriously lessen either that of labor or capital, but only those which may be cheapened by *mechanical appliances.* At present, however, they lack financial strength, and the stimulus and opportunity for testing inventions afforded by a large and regular demand for their work. To whom can they look for this demand? Not to foreigners, who can buy cheaper abroad. They can effect it only through their own countrymen." This paragraph cuts right at the heart of the matter, lays the question bare; then with patriotism bids the ship-builder look to the American ship-owner. We feel the time is indeed auspicious, to tell the ship-owner he can buy his vessel at a reduced cost—and being told, good faith must follow.

Here, then, is the sore spot; *cost of construction* is the great obstacle in the way of the American iron ship. But now national pride is aroused, and, despite this excessive cost, our pioneer vessel lies at her wharf loading for Liverpool. However, gentlemen, we are here this evening to unitedly throw a stone at this Goliath, and I hope to be able, before I close, to bring conviction to your minds that the question is virtually settled, and requires simply practical development.

Ship owners have inspired the newspapers, and the latter have stirred many hearts in the country with the desire to see the American flag represented on the ocean as befits the dignity of the nation. This wave of desire has passed on to Washington, and has an earnestness of meaning that is unmistakable. But let us have a care, since too much precipitancy is often ruinous.

Let us review what is being asked, and in the first place we find one clamoring for a monopoly, a second sueing for bounty, and a third asking for subsidy.

In regard to this aspect of things, we must say, firstly, and with emphasis: We don't believe in monopolies! A monopoly implies,

indirectly, the suppression of individual effort. Individual effort implies competition, and competition is the life of trade.

The scheme of bounties we regard as dangerous, since there can be little justification in Government giving gratuitous aid to any manufacture, or business undertaking, especially when it questionably seeks it. Were such a thing absolutely necessary, we think ship-building and ship owning, through its national character, would be better justified in seeking and accepting such aid than anything else; but this is qualifying, and the necessity does not appear.

It is the duty of the Government to pay an equivalent for value received, so give subsidy where a mail is carried, or where other work is performed; but beyond this, it is the writer's opinion, we are better away from Government aid, except the protection in national rights.

Viewing the subject of our commercial marine as a ship-builder, I intend speaking from a practical standpoint, and presenting for your consideration some ideas of a practical nature on the subject.

I may state at once that in seeking a remedy I go to the root of the matter, that is to the ship herself; and shall seek to place my finger on the weak places of iron ship construction, and develop ideas and designs which, you will discover, deal directly with material and labor, items which are the basis of cost.

The first I reduce in weight, by using more suitable sections, or forms of iron, and by placing the iron in the vessel so as to give the greatest strength to her structure. The second, I reduce in cost by performing with machinery what is now done by hand. I here give an outline of the propositions which I hope to sustain, but before proceeding with the details of my own views it is needful that defects in the present method of construction should be pointed out.

When the wooden ship-builders of half a century ago turned their attention to iron, as a material for ship-building, they possessed but an imperfect knowledge of the material with which they had to deal. Accordingly, as was natural, they followed the system of building with which they were familiar. That system is commonly known as the transverse framing system; that is, the frame is run across the ship right angles to the keel, and extends up to the gunwale in a vertical direction. The necessity for such a plan of construction in a wooden ship arises from the fact that the planking has no edge connection with itself; therefore it must have an indirect connection, attainable

only through the framing, making the framing, therefore, the most important part of the structure.

Wooden ship builders, imbued with this idea of transverse framing, and being familiar with its execution on the loft floor, carried it out in practice when their attention was given to iron.

In her main features, the iron ship of to-day is the same as the iron ship of years ago. We, of course, find some improvements. These, however, may be traced as much to the iron manufacturer as to the ship-builder, since it is now possible to obtain what was before impossible, namely, material of almost any dimensions. Plates now go on the ship of quadruple their former size, giving a better arrangement of butts, and a reduction of fastenings, and though the plates are worked as "in" and "out" strakes, instead of being clinker built, yet the original principle of ship construction remains. Improved machinery has added its quota, and has greatly aided in bringing the iron ship of to-day to its advanced position.

In reviewing the iron ship as now built, we find her keel in most cases, when draft of water permits, of solid bar iron, say $8\frac{1}{2} \times 2\frac{3}{8}$ inches in a 1,000 ton ship. These bars are usually connected by scarphs, in length nine times the thickness of the keel, and are rivetted together by three or four small rivets, which would break were the keel even partially suspended and its weight allowed to test them. This fact shows unfavorably the value of a solid bar keel, strong in its several pieces, and weak in its connections. But we are told it is strengthened by the flange of garboard strake, which is bent in accordance with the angle formed by frame and keel. Yes, it is strengthened, of course; but do we get the strength out of it which we should fairly expect from its weight? By no means. At the scarph, it is like a double plate with its butts shifted only $21\frac{3}{8}$ inches apart; were it two plates, instead of a solid bar, in point of strength it would take precedence over the bar, as the butts could be shifted at least nine feet apart, and opportunity afforded of connecting it with centre keelson.

We appreciate the advantages a ship derives from a keel, but do not appreciate this arrangement, which is little more than five tons of packing or material without mechanical application.

There are other improved descriptions of keel adopted, but the one described is the one in general application, where draft of water permits.

The frames, as past and present practice use them, are of angle iron in accordance with size of ship, and run across the keel at right

angles, and vertically up the side; that is, are transverse in their direction.

Each frame, as a whole, is composed of three parts: the frame proper, or angle iron coming against shell; a floor plate, the name given to the plate which runs across the bottom, and turns up the bilge to a height of twice the centre depth; and a reverse frame running across top of floor plate and up the side of ship, attached to moulding edge of ship's frame at inner side. These are all securely rivetted together, and are spaced from 21 inches to two feet apart, all fore and aft the ship.

There has been a gradual tendency to stretch out these frames, as the fact has become manifest that the *skin resistance is the great point of strength in an iron ship.* Lloyd's early rules, and the first practice of ship-builders, approached as nearly as possible the wooden ship-building idea of close framing, which is requisite in a wooden ship, owing to the poor description of fastening and the absolute necessity of obtaining as much fastening as possible. With iron it is, however, totally different, and how ship-owners can require, and still more wonderful, how ship-builders will build, except under protest, vessels on a system that ignores and degrades science, when they have the knowledge that the ship's strength is *in her plating*, surpasses conception.

I appeal to you, ship-owners of Philadelphia, to sweep away this evil. You are paying more for your vessels than is necessary, and for your money you are obtaining anything but mechanical structures. You are obtaining ships which, despite the British Lloyd's, the Liverpool Registry, the French Veritas and the American Registries, or the approval of any other body, is a libel on the dictionary to call first-class, without adding the saving clause—*Transversely Framed Ship.* A ship, first-class, that is holed all round her at each frame, the distance apart of holes being merely six inches, and she subject to racking and twisting at sea, as she passes from mountain to mountain of water, straining and straining again! Can any one point me out a stronger argument in favor of the *tower of excessive strength possessed by the present iron ship, through the introduction of excessive material, than this: that she can be made rigid by the introduction of a frame, and at the very point of rigidity can be weakened by punching away her material until she is at each frame ⅓ weaker than the solid plate?* Yet, professedly, the frames are put in for strength. Delusion! Once overlook the fact that the shell is the

main strength, is *the* strength of the vessel, and error need not be wondered at.

The framing of an iron ship is but an auxiliary; why, then, make the plating subservient to it? Why weaken the plating for the sake of it? Let us have no more such work; tear out the inner structure, and dispose the iron to better advantage.

Having spoken, as I have, of the general framing of the ship, what shall I say—what are you prepared to hear respecting the Bulkhead frames that are introduced in iron ships? These frames generally count two amidships, one before and the other abaft the engines. They are usually double frames, that is, double angle irons, back to back, with bulkhead plates between. The object of the bulkhead is to give the ship water-tight compartments. It accordingly has to be caulked, and made thoroughly water-tight.

Experiment proves that, in order to make a properly water-tight joint in rivetted work, the rivets must not be spaced more than four diameters apart. This accordingly necessitates the punching of frame and plate with holes, not six inches apart as in rest of framing, but three inches apart, thus reducing the strength of shell about $\frac{1}{4}$ of solid plate.

I have referred to the rigidity of an ordinary frame, but how can its rigid power compare with that given to the frame of a bulkhead which is plated solid across the ship and stayed by angle irons. It is true attempts are made to extend the rigidity over the shell and reduce the effect of close holing by introducing liners in way of outside strakes, and knees alternately on forward and after side of bulkheads, thus partially attaching bulkhead to shell indirectly; but with the shell weakened nearly one-fourth, and a rigid frame calling the attention of every strain to it, we need not feel surprised should we hear of a long, shallow steamer breaking off at her bulkheads.

Nor need we be surprised at hearing of a *full* bowed steamer being stove in by ice in coming up the Delaware, when we remember that, by placing the frames one distance apart all fore and aft, as we approach the ends, there is less plate stayed by frames than amidships; for while the frames are the same distance apart on a square line, yet on the run of the water line the distance is greater, by reason of the fact that the base of a triangle is less than its hypotheneuse.

Transverse framing has yet another disability, namely, the bevelling which it has to endure to enable the outside flange of frame to be flat upon the plate at the ends of vessel. This bevelling com-

mences immediately the side of a ship alters from her midship shape, and increases rapidly at the ends, where the iron is greatly injured by being opened from the right angle to the obtuse angle required.

So severe has the punishment been to the metal, that I have frequently seen the angle split right open in the throat, which is the place of greatest strength. The weakening had gone on by degrees, as the bar was opened or bevelled until the iron finally gave way. (A specimen of bevelled iron thus split was here exhibited by the speaker.) It would be interesting to know how many frames in the present iron ships afloat were just on the point of splitting open when the workmen eased up on them. This state of things is not right. It is a matter of grief to a true mechanic to see material abused, and a hardship to be compelled to put iron into a ship which he knows to be ruined. If the material is not giving proportional strength for weight take it out; change the section of iron, change the arrangement, change the system, change the modes of working the material, or change yourself if you can't do it.

I have pointed out how a ship is weakened longitudinally by transverse framing—weakened in the line of desirable increased strength, as she would certainly break in two through leverage of length were she to give way at all, as her length is from seven to nine times her breadth, and from ten to fifteen times her depth.

In present mode of construction we have a strange anomaly. *The ship is weakened in the direction in which she is already the weakest*, i. e., *longitudinally, then longitudinal strength is applied in the form of keelsons to regain her loss of strength.* Certainly a brilliant mechanical device, but certainly a most un-American mode of procedure. We should not weaken our ship, then we shall not require *extra material and fastenings;* and if the material we do use is made to fulfil more purposes than one, we reduce the weight and cost, and exhibit skill in place of bungling.

The keelsons now employed to give longitudinal strength are various in form, and consist of, first, a middle line keelson; the general form, when a bar keel is used, being that of a plate of certain depth and thickness, with double angle irons at top and bottom. This keelson is connected to double angle irons on top of floor plates at middle line by four rivets to each floor, that is, four rivets for each space of twenty-one inches, fore and aft distance. This shows up a lattice arrangement, for the keelson bridges the transverse floors, or comes in contact with them at distances of twenty-one inches, thus

piling up the iron, instead of being a floor itself, running fore and aft, thus being floor and keelson in one, saving weight and having an equally spaced arrangement of fastenings, instead of a cluster of fastenings, then a lengthened space, and again another cluster of fastenings. The middle line keelson is sometimes formed as a box, at other times worked intercostally between the floors, which gives a more compact arrangement. This intercostal arrangement is usually supplemented by being extended above the floors, either in the form of middle line keelson as described, or cut off at a level of lower angle irons on top of floors. Another form of centre keelson is that known as a centre through plate keel and keelson, which is a deep, continuous plate, having the floors cut at centre to allow it to run all fore and aft. There are double angle irons at bottom running fore and aft; again similar ones are fitted on a horizontal plate, on top of floor, at each side of centre, connecting keelson and floor through the medium of horizontal plates. A further connection between floor and keelson is effected by vertical angle irons in the corners, so that the whole is efficiently bound together. This strength is, however, made up entirely by additional weight, as indeed is the longitudinal strength obtained by all. The other keelsons in the ship, such as side intercostal keelsons, at half floor, are composed of plate and angles running fore and aft. Lower and upper bilge keelsons are formed of double angle irons, back to back, and rivetted to inside of frame or top of floor, and also extend fore and aft. I wish it distinctly seen that to obtain longitudinal strength, the *strength most required*, owing to length being greater than breadth and depth, the present system of shipbuilding is to first weaken the ship one-eighth at section of each frame and one-fourth at section of each bulkhead, making her at the same time more rigid at these points and liable to receive a strain there. After she is weakened, several tons of material, in the shape of keelsons, are put in to give her back her reduced strength, which, however, falls short in restoring the loss, as the sectional areas of material will show. In a 1000 tons ship, built on the transverse system of framing, the sectional area of shell plating at midship section equals 640 square inches, which is reduced about one-fourth in way of bulkheads, by punching the frame all round to make bulkhead watertight; this reduction equals 160 square inches. Now, to keep up the original strength, we ought to make up the deficiency of 160 square inches which is punched away, and also give an excess to strengthen the ship longitudinal, as she is weakest in that direction. What is the

present practice? It is this: A middle line keelson is required of plate 14 inches deep by $\frac{11}{16}$ inch thick, having at top and bottom double angle irons $5 \times 3\frac{1}{2} \times \frac{8}{16}$, altogether giving a sectional area, without deducting punchings, equal to 26·62.

There are also three other keelsons aside of double angle iron $5 \times 3\frac{1}{2} \times \frac{8}{16}$, back to back, which totals, taking both sides together, 51 square inches, and added to middle line keelson, gives a grand total of 77·62 square inches, added to sectional area by introduction of longitudinal keelsons, against 160 inches taken out by punching at bulkheads, *leaving a deficiency of* 82·38 *square inches on original strength of material, where the ship really requires an addition to original sectional area. The fact of introducing liners, too clearly exemplifies the general system of ship construction, which is to first weaken the structure, then throw extra weight of metal to alleviate the weakness.* In way of the ordinary frames, I stated that $\frac{1}{8}$ sectional area was punched away, which would make a deficiency by punching of 80 square inches, against an addition of 77·62 square inches by introduction of keelsons. We here see the vessel absolutely has no fastenings to strengthen her in accordance with the dimensional proportions of structure, for the extra fastenings introduced are thrown away in attempting to overcome the weakening of structure by introduction of transverse frames.

We can now reply to the question, how is it we can't build as cheaply as the British ship-builders? by answering that in spite of the increased cost of labor and material here, we are trying to emulate them in throwing away material and workmanship upon it—and *we* can't afford it.

But can we compete with them? Yes! I believe so, in a little time, if we don't follow them and their registry rules for the construction of iron ships.

Let us briefly show another help to this side before continuing our discussion. Two years and a half ago ship plates could be bought at £8,10 per ton at the other side; now I see the quotations range from £15 to £17 per ton, £15,10 being the latest quotation. Again, coal has gone up to famine prices, and labor is feeling the effects produced by the vessels it equips, carrying a steady stream of mechanics from Europe to America.

A careful estimate at exact present prices of labor and material shows a difference yet, in favor of British ship-builders, of 17·94 per cent., but so vast has been the reduction in two years that every

effort must be made to secure, not only our own iron ship-building, but the iron ship-building for the world.

All this, however, should make us the more wary, for there are men of energy and vast ability at the other side, who will fight the battle with vigor; but for them to bring about a change is difficult, for the registries, serpent like, are coiled round and round the British ship. She must have a character, accordingly must be built to rule; thus the ship-builder and ship-owner are floundering in the mazes of a prodigious web. Europe is chained by a mass of rules that will hamper her almost inextricably in attempting to part company with old fashioned ways, while America is free in thought and has nothing to hinder her from taking the shortest cut to accomplish an object.

I must pass in review before you the upper part of the present ship, and as all the decks are similarly constructed and fastened, whether it be spar, main, lower or orlop deck, I shall confine myself to the upper deck. Here, at the deck, we discover the weakest point of the iron ship, but it is much better attended to now than originally; a few years ago the beams were of poor sections, or rather were made up of several sections of iron rivetted together; now, however, we find them of a good form of iron generally, known as T bulb. These beams run across the ship, and are attached to the frames by welded knees. The spacing of beams is from 3′ 6″ to 4′ 0″ apart, or one to each alternate frame. On top of the beams, at side of ship, is rivetted a stringer plate, which assists indirectly to connect beams with the side, as the stringer plate is connected to sheer strake by a continuous angle iron round the gunwale; much attention has of late been paid to this stringer plate, and rightly so, for this is the point where the ship is weakest, and I wish your attention paid to this part, as it still continues the weakest place, one of the chief reasons being that the beams are improperly connected to the side, as by their present fastening they give out their strength principally locally, whereas it should be distributed along the side, as I shall show it in describing my vessel. This is a matter of very great importance, for if a ship works at all, it is at the connection of side and deck, which is quite natural, as the strength of side suddenly stops here. I have known ships undergoing their periodic survey to have nearly all the rivets connecting beam knee to frame found loose, which practically points out the sore spot.

Great attention has lately very properly been paid to the pillaring of iron ships. Formerly there was no connection between the

deck and the bottom of vessel, but now the different registries and builders make a decided point that all vessels have a pillar to each beam through midships and each alternate beam at ends, which acts as a tie or stay between the extremities of deck and bottom, and is of considerable value.

The latest addition to the iron ship is the iron deck; and in the transversely framed ship, weakened as the vessel is shown, it should be regarded as a necessity when the ship is of considerable length. A ship, in many respects, may be viewed as a box girder, only hitherto the fourth side has been left unenclosed; but by giving the vessel an iron deck we close all in, and complete the structure, *and the structure is good or bad, as you view the shell as the main strength, and stiffen it by auxiliaries at the inside, so as least to puncture the shell, giving the direction to your internal strengthenings that the form and dimensions of structure calls for.*

I have endeavored conclusively to show that the transversely framed ship does not come up to this standard, and before proceeding to develop a vessel that will respond to this call of excellence, we shall refer to the present mode of fastening, with its necessities and its faults.

Rivetting, as you are all aware, is the general method of connecting the various parts of an iron ship, and, as is natural, much attention has been paid proportioning and disposing the rivets, and giving to the plate the most efficient amount of lap. This system, the best hitherto practised, we shall, however, show to be far from perfection, as the vitality of the iron is injured by punching, which is the usual and best method of perforating the material in proportion to cost. Drilling has been resorted to, and has an advantage in point of strength; but it is too slow in its operation and too costly ever to be generally adopted. We say the vitality of the iron is injured by punching, and in support of this view I shall quote you briefly from E. J. Reed's work on "Ship-building in Iron and Steel." He says: "It has been established by direct experiment that when a row of holes has been punched in a plate, the tensile strength of the iron left between the holes is considerably reduced, whereas with drilled holes the strength remains almost unaltered. This is still more strikingly the case when holes are punched in steel plates, as shown in the preceding chapter. In iron plates the reduction in strength made by punching is considerable. For example, with the pitch of rivets usually adopted for water-tight work the tensile strength of the iron taken along a section through a row of rivet holes has been found to be from 16 to 18

tons per square inch of sectional area, whereas for the unpunched plates it has been upwards of 22 tons per square inch. *It will be obvious that the large factors of safety employed in proportioning the scantlings of the various parts of ships and other wrought-iron structures, render these experimental facts comparatively unimportant in relation to the consideration of the ultimate or breaking strength.*"

I request you to give these words your closest attention, as they bear full upon the point I contend for and build upon, namely, that the present transversely framed iron ship is the most prodigal mechanical structure (in material and labor) to be found in the universe. Mr. Reed calls it possessing *large factors of safety*, and in that we agree with him, *very large*. Consequently, by rightly disposing her parts, weight and cost can be reduced. Mr. Reed continues: "But, with regard to the arrangement of proportions of butt fastenings, where the principal object aimed at is the preservation of continuity of strength, it becomes absolutely necessary to take into account the reduction of strength caused by punching, in order to arrive at a correct result. It may be added that, although this is not commonly done in arranging butt fastenings, in the investigation of rivetted work given further on in this chapter, we shall take this reduction of strength into account, and assuming the tensile strength of the plate iron lengthwise to be 22 tons per square inch before being punched, shall, in most cases, take 18 tons as the strength of the iron left between the holes after the punching has been performed."

To show you the exact difference between punched and drilled holes, I shall quote experiments made by Mr. W. H. Maynard, upon punched and drilled bars cut from the same plate, parallel to each other. The holes were about one inch in diameter, and drilled in two of the bars; the other two were punched so as to leave exactly the same section of metal in the plate as in the case of those drilled, namely, about 1·5 square inch at the part reduced. The results were as follows, showing a mean of 19 per cent. in favor of drilled plates.

Experiment.	Drilled bar broke with a tensil strain in tons.	Punched bar broke with a tensil strain in tons.	Difference in tons.	Difference p. c. in favor of drilled bars.
1st,	30½	26	4½	17
2d,	31½	26	5½	21
Mean	31	26	5	19

Mr. Maynard has also experimented upon the shearing strength of rivets in punched and drilled holes, as follows:

Five-eighth inch rivets in drilled holes.

Single shear = 26 tons per square inch.
" = 26·4 " "
Double shear = 39·2 " "
Second experiment failed.

Five-eighth inch rivets and punched holes.

Single shear = 27·2 tons per square inch.
" = 26·0 " "
Double shear = 45·6 " "
Second experiment failed.

Mr. Maynard says: "I consider the above as conclusive that rivets in drilled holes, subject to shearing strain, were about four per cent. weaker than rivets in punched holes under similar strain. I think that the sharp edges of the drilled plates have a greater tendency to snip off the rivets than the rounded edges of punched holes."

The summary of his experiments seems to be—

1st. That drilled plates are stronger than punched by 19 per cent.

2d. That rivets are weaker in drilled holes than in punched, by 4 per cent.

3d. That the difference is in favor of drilled work by 15 per cent.

The great point to settle in rivetted work, however, is how does the rivetted joint compare with the solid plate? Is it as strong? Is it stronger or is it weaker? We must again resort to experiment to settle this, and find that Mr. Fairbairn has experimented upon single and double rivetted joints, with the following results:

Taking the strength of the plate as = 100, the strength of the double rivetted joint would be = 70, and the strength of the single rivetted plate = 56. This settles positively that rivetted work is inferior in strength to the plate in the proportions of 70 and 56 to 100; or less than three-quarters and very little more than one-half as strong for double and single laps respectively.

Rivetting, then, as a mode of fastening, must be abandoned, and I particularly desire your attention to the fact that I obviate this source of weakness, and save material and labor, thus cheapening the construction of iron ships by welding my ship, which brings her up to the original strength of plate.

I now pass from the transversely-framed ship to what has been done and can be done by other systems.

(To be continued.)

AMERICAN SOCIETY OF CIVIL ENGINEERS.

A regular meeting of this society was held at the rooms in New York, March 5th, 1873.

A paper on "Shaw's Gunpowder Pile Driver," by Samuel R. Probasco, C. E , of Brooklyn, N. Y., was read.

This Pile Driver was set at work in October, 1872, on a line of sheet piles for a reservoir dam in the valley of Parsonage Creek, Long Island. The material to be penetrated was sand and fine gravel, cemented together in places, so as to be hard and difficult to move with a pick, and like "hard pan." Clay was found below the water level of the basin; some borings showing it at fifteen feet below the surface; the lower stratum was tough and tenacious, and the whole material was under water.

The machine in form resembles an ordinary pile driver; a cast iron block, called a "gun," resting on the head of the pile, is bored out, and receives without windage a wrought iron piston attached to another cast iron block, called the "ram," which is lifted by explosion of powder in the bore. When the piston leaves the gun, a cartridge is thrown in, which, exploded by the heat freed by the piston in its descent, throws the ram upwards again, and forces the pile downward. The area of the piston is adjusted to the weight of the ram, which also is adjusted to the work to be done. Soda powder cartridges in cylinders of $1\frac{1}{4}$ to $1\frac{1}{2}$ ounce, coated with black lead and paraffine are used. The coating is expected to keep the powder dry, lubricate the gun, preserve the requisite tightness, prevent escape of gas, and cause the entire force to be exerted on the base of the piston.

The piston is made a little smaller than the bore of the gun, and has on its lower end a steel ring which fits the bore closely. The performance was as follows:—At first several explosions were necessary to lubricate the gun, which leaked gas so that the ram would not go to the requisite height to move the pile. After a few shots, the piston moved up regularly, and in its descent fired the charge, forcing the pile down and itself upward. When the resistance is slight, this machine may be economical, but when, as in this case, it required 300 blows from cartridges costing $2\frac{1}{2}$ cents each to force a pile down 15 or 16 feet, it cannot be called so. The gas from the explosions cut passages in the ring at the end of the piston, and thereby much lessened the power of the machine. The gun became hot from the rapid discharges, and the bore enlarged, whereby more gas escaped. Seven

piles were driven with it—each costing more for powder than the contractor got for piles in place—when the machine refused to work. On examination, the steel ring was found furrowed by the powder, and the piston (diameter five inches) so bent by striking the bottom of the gun, as to be useless. The air-cushion relied upon to prevent this, was lost by the furrowing of the ring. The inventor, on being consulted, decided that the excessive consumption of powder was due to the piston being too small for the ram, weighing over 1700 pounds. The bore of the gun was then enlarged to receive a piston seven inches in diameter, and ten piles more driven, when the machine was again laid aside. The result of this trial was similar to the first, except that the piston was not bent. The gun got so hot as to fire the powder before the ram reached its place. Altogether, seventeen piles were driven to a depth of from fourteen to nineteen feet; requiring from 200 to 300 blows of 1½ ounce cartridges. An ordinary pile driver was then employed, with a hammer weighing 1800 pounds, and falling eight to ten feet. In this way, eleven piles were put down 15½ feet in ten hours—costing per pile no more than 100 blows from the powder machine. These 100 blows, at best, would put the pile down but ten feet.

The piling was spruce, from $10'' \times 10''$ to $10'' \times 14''$—20 feet long—with 2″ square tongue and groove. The piles were bevelled at the point on three sides, leaving the grooved side untouched. The groove was driven on the tongue of the preceding pile. The heads were protected with a light band. Seven piles were driven without shoeing; the eighth split, and showed the necessity of protection at the point. A cast-iron cup shoe, weighing about forty pounds, with a groove in it, and made with three bevels and one plain side, was found to stand the work. The tendency of the tongue of the pile to work up was obviated by twisting a chain tightly about the pile and tongue; a lever with rope attached was used for this purpose, the force being applied as the blow was delivered. Seventy-five piles were driven in this way to a mean depth of 15½ feet. By experience, 6″ more depth has been attained, which is about the maximum penetration in this kind of material, and this can only be done with the best of sound, dry spruce.

A brief discussion followed. After which a paper on "Rail Economy," by C. P. Sandberg, C. E., of London, England, in reply to the discussion had upon a former paper of his on the same subject, was read.

In that discussion it had been remarked, under the head of "Traffic

Capacity," that the weight on locomotive driving wheels, stated therein, differed from American practice—that on the Philadelphia and Reading Railroad, four tons on drivers were not exceeded for a 64 lb. rail, and that on the Erie Railway, 5½ tons had been found too much for a 70 lb. rail.

Mr. Sandberg herein replied that it would be interesting to know what weight the rail and the rail-joint would carry in the two instances mentioned. 6¼ tons on drivers on a 60 lb. rail, as stated in the table, and considered excessive, might not be so; the table showed that the 60 lb. rail of standard section with fishplate would carry 14 tons in the middle between three feet bearings, and 9¼ tons at the joint between two feet bearings. According to the table the maximum load on drivers on standard sections was one-third what the rail in the middle would carry, and two-thirds of what the rail-joint would sustain. In order to obtain the full value of the material, the joint ought to be as stiff as the middle of the rail. For this it is best to use the fishplate as thick as will not interfere with the tyre-flange; the angle should be as small as will permit an easy rolling of the rail. This angle is 11° and 15°, the latter for light rails, experiments having proved that the smaller the angle the stiffer the joint. With this fishing, the capacity of the rail at the joint is two thirds that at the middle, while with ordinary fastenings it is but one-fourth. In regard to the Erie sections, experiments have shown that this rail will bear at the joint but two tons, while at the middle it will carry ten tons; hence it is not strange that 5½ tons on the drivers proved disastrous. The necessity of sufficient thickness in the fish-plates is often overlooked. It is doubtless prudent to increase the number of drivers on American roads, but the statement that 6¼ tons on a 60 lb. standard rail section with standard fastenings, is excessive, should be modified. This load is not the most economical for working a line, but that to which an increase of traffic might extend.

Many European railways with a 70 lb. section have a joint carrying only six tons, owing to too large an angle and too thin a fishplate.

Improvements in Canal Navigation.—The Legislature of New York, we learn, has lately renewed, for the period of one year, the offer of one hundred thousand dollars for improvements in canal navigation, of which the general outlines, together with a description of the tests to be applied, has already been named in the Journal.

GAUGING OF RIVERS.

By Bvt. Brig. Gen. Henry L. Abbot, Major of Engineers.

(Continued from page 393, Vol. LXV.)

To try the formula arithmetically upon these new data, I have selected three observations; of which the first was made with especial care for a particular purpose; the second was in the deepest trough, thus having the velocity measured at the largest number of points; and the third (made by M. Baumgarten) was upon the canal Marseille with an earthen bed, the others being in wooden. To multiply the number of observations at each depth, as far as can be done without vitiating the curve by introducing the influence of the sides, I have taken a mean of the three central curves in the troughs, and of the five central curves in the canal. The following tables exhibit the data and the results obtained by applying the general equation on page 392, Vol. LXV. The depth of the axis is assumed so as to dispose the observations symmetrically upon the parabola; and the value of the maximum velocity is fixed by the condition that the sums of the observed and computed velocities shall be equal—throwing out in the second observation the lowest, and in the third observation the highest and lowest measurements, as probably vitiated by one or both of the above causes of error. The "strong wind" blowing at the time renders it extremely probable that this was the case.

Series 53. *Sub-surface Velocity Observations.*

Bed, poplar plank. Width, 2·63 feet. Depth, 0·82 feet. Mean velocity, 5·123 feet. Day calm. Depth of axis, 0·1 ft. or 0·12 of total depth. Maximum velocity, 6·113 feet.

Vertical plane.	Velocity at following depths below the surface.			
	0·10 ft.	0·36 ft.	0·56 ft.	0·72 ft.
	ft.	ft.	ft.	ft.
Left of middle 0·36 ft.	6·076	6·010	5·472	4·289
Middle of canal	6·376	6·046	5·492	4·667
Right of middle 0·36 ft.	6·046	5·968	5·390	4·468
Mean	6·166	6·008	5·451	4·475
By formula	6·113	5·873	5·363	4·751
Discrepancy	+0·053	+0·135	+0·088	−0·276

Series 64. *Expt.* 2. *Sub-surface Velocity Observations.*

Bed, plank covered with strips 0·08 feet wide, spaced 9·16 feet apart. Width, 6·5 feet. Depth, 2·16 feet. Mean velocity, 3·111 feet. Wind very strong up stream. Depth of axis, 0·6 ft. or 0·28 of total depth. Maximum velocity, 3·981 feet.

Vertical plane.	Velocity at following depths below the surface.						
	0·10 ft.	0·43 ft.	0·75 ft.	1·08 ft.	1·41 ft.	1·74 ft.	2·07 ft.
	ft.	ft.	ft.	ft.	ft.	ft.	ft.
Left of middle 0·66 feet...	3·763	3·872	4·031	3·953	3·679	3·316	2·296
Middle of canal...	3·929	3·982	4·112	4·034	3·873	3·471	2·389
Right of middle 0·66 feet.....	3·820	3 901	4·059	4 006	3·845	3 375	2·296
Mean.....	3·837	3·918	4·068	3·998	3·799	3·387	2.327
By formula.....	3·893	3·971	3·973	3·909	3·745	3 521	3·220
Discrepancy	—0·056	—0·053	+0·095	+0·098	+0·050	—0·134	—0·893

Canal Marseille. Expt. 7. *Sub surface Velocity Observations.*

Earthen bed. Width, 19·7 feet. Depth, 4·36 feet. Mean velocity, 2·536 feet. Wind strong down stream. Depth of axis, 0·1 ft. or 0·02 of total depth. Maximum velocity, 3·283 feet.

Vertical plane.	Velocity at following depths below the surface.						
	0·07 ft.	0·30 ft.	1·18 ft.	2·00 ft.	2 99 ft.	3·60 ft.	4·07 ft.
	ft.	ft.	ft.	ft.	ft.	ft.	ft
Mean of 5 central curves	4·039	3·301	3 156	3 074	2·674	2·432	1·647
By formula	3 282	3 280	3·201	3·031	2·699	2·427	2·181
Discrepancy	+0 757	+0·021	—0·045	+0 043	—0·025	+0·005	—0·534

The result of this comparison of formula and observation is satisfactory, for not only are the curves parabolas with their axes submerged and evidently affected by the wind, but even their degrees of curvature are closely predicted by the equation. To continue the investigation and fully discuss in this manner all the data furnished by MM. Darcy and Bazin relating to the laws governing the action of cohesion, would be extremely interesting, and might probably result in extending and perfecting the expression for the parameter —which for very shallow depths, where its variation is most rapid, is based upon only two observations made by Capt. Boileau—but such an analysis would hardly come within the scope of this paper.

M. Grebenau has confirmed our law for the action of cohesion, both by original observations and by collating older data. He gives a plate which represents these results to the eye in a striking manner, and sustains his conclusion that the law is obvious in all the earlier observations as well as in his own. He accounts for its non-discovery before, by the fact that graphical analysis was not used.

Gen. Warren's unpublished data upon the Upper Mississippi, also confirm our parabolic law; as, indeed, do other recent measurements.

Observations also show that in horizontal planes, as well as vertical, the law of transmission of the resistances experienced at the banks, is parabolic. Indeed, this conclusion logically follows from the foregoing principles, since the cohesion of the different particles to each other must act in the same manner in whatever direction the disrupting force is applied. Unfortunately, however, in horizontal planes the law of transmission is usually obscured by the set of the current, by variations in depth, and by other local agencies. At Columbus, Ky., the entire horizontal curve of the Mississippi was a parabola whose parameter varied precisely in accordance with the laws governing in vertical planes parallel to the current. At other localities, the horizontal curves seemed to be made up of arcs of different parabolas combined in so intricate relations as to defy analysis.

The difficulty which it was foreseen would cause our formula to indicate too large velocities when applied to very small cross sections can now be understood. Equating the expressions for the accelerating and retarding forces, as explained above, and reducing, the following equation results; in which U_o and U_r denote respectively the mean of all the surface and the mean of all the bottom velocities.

$$\frac{a\,s}{p+W} = f\left(\frac{U_o\,W + U_r\,p}{W+p}\right)$$

Now to deduce the *mean velocity* from this equation, it is necessary to introduce for U_o and U_r their equations based upon the vertical and horizontal parabolas indicating the action of cohesion. For the vertical curve this was done in framing our formula; but the complex nature of the horizontal curves eluded research, and we were compelled to use the following empirical expression, in which U_m denotes the grand mean of all the mean velocities in all the different vertical planes parallel to the current.

$$U_m = 0{\cdot}93\ v$$

This expression, (see page 290 Physics and Hydraulics of the Mississippi) accords very well with observations upon natural channels of the size of those upon which our observations were made, but it was clearly perceived that it really involved a variable function of the parameters of the arcs of parabolas of which the horizontal curve is composed; as well as a function, probably nearly constant for rivers, dependent upon the form of cross section and the number and lengths of the arcs of the different parabolas. In other words, theory required that the expression should be written.

$$U_m = A \sqrt{\frac{B\,v}{\sqrt{C + W}}}\, v = A \sqrt{\frac{B}{\sqrt{C + W}}}\, v^{\frac{3}{2}} = A \sqrt{b'}\, v^{\frac{3}{2}}$$

It is evident from the form of this expression,—in view of the necessarily small numerical values of B and C relative to that of W,—that it must be sensibly constant, except for very small values of W. That we were correct in this assumption is shown by the close accordance of our formula with observations upon ordinary natural channels. The little canals of MM. Darcy and Bazin furnish data in which, from the small values of W, the constancy of the numerical value of b' is destroyed; and, in consequence of the manner in which it enters the equation, the formula must indicate too large velocities.

To recapitulate in general terms, b, the function of the depth entering the expression for the parameter of vertical curves, is essentially constant until the depth is reduced to about a dozen feet. These data of MM. Darcy and Bazin indicate the same to be true for the function of the width entering the expression for the parameter of the horizontal curves. It remains, therefore, to consider how to correct the formula to suit very small natural streams, by introducing a known function of the width as a variable.

Making the substitutions and reductions indicated upon page 300 Physics and Hydraulics of the Mississippi, and substituting for 0·93 v the value just given, the general expression for $\frac{a\,s}{p + W}$ on the opposite page, becomes:

$$\frac{a\,s}{p + W} = f\left(A \sqrt{b'}\, v^{\frac{3}{2}} - 0{\cdot}167 \sqrt{b}\, v\right)$$

By a process similar to that employed in deducing the form of the

function composing the second member of the analogous equation on page 311 Physics and Hydraulics of the Mississippi—determining the value of the constants in the expression for A $\sqrt{b'}$ by a tedious method of approximation applied to the new data for the feeders Grosbois and Chazilly—it would be possible to arrive at a general equation for the mean velocity, applicable to cross sections less than 100 sq. ft. in area, as well as to large rivers. It has not seemed to me advisable to adopt this method at present, partly because the resulting formula would be inconveniently complex, and partly because, as a preliminary step, the equation for b for very shallow depths, say less than 4 or 5 ft., should be carefully studied. The data used in fixing this part of the curve when the formula was framed, were meagre, and it may be that a thorough analysis of the new and more extended sub-surface velocity observations of MM. Darcy and Bazin, would, beside introducing a function dependent upon the nature of the material composing the bed, indicate a slightly increased curvature. A hasty inspection has led me to surmise that the latter would be the case; if so, the effect upon our general equation for v would be to slightly diminish the computed values of that quantity for very small channels (without affecting them for rivers) and would thus reduce the amount of the correction now attributed to the influence of the diminished width. A thorough and laborious analysis of the whole subject for *very small streams* is desirable, pending which, since b' is sensibly a variable only for the smallest channels, it has seemed to me advisable to use a more simple method of introducing the width correction for such cases, by appending as a subtractive term a function of the width and mean velocity analogous in form to the expression for the parameter of horizontal curves.

The most simple and convenient form for such a term, is the following, in which v' denotes the mean velocity as first computed, and u the amount to be subtracted from that velocity to reduce it to the true mean velocity. A and B are constants. The wetted perimeter is used instead of the width, because for this purpose it is essentially the same in value, and is given exactly in the reported observations, while the width is not.

$$u = \frac{A \sqrt{v'}}{B + p}$$

From a careful discussion of the 28 observations of MM. Darcy and Bazin upon the feeders Grosbois and Chazilly, A is found to be

2·4 and B to be 1, making the expression for the reduction in mean velocity resulting from a diminution in width, through its influence upon the parameter of the horizontal curves, become

$$u = \frac{2{\cdot}4\sqrt{v'}}{1+p}$$

Assuming for the moment this expression to be correct, it is interesting to roughly compare the relative effects of proportional reductions in depth and width upon the mean velocity, due to the influence such reductions exert upon the parameters of the parabolas which define the law of transmission of resistances through the fluid mass. It will, of course, be borne in mind that the controlling effects of such changes in cross section are taken into account by the expression

$$\frac{a}{p+W}$$

Take, for example, the Mississippi river, 2600 feet wide and 80 feet deep, and flowing with a velocity of 4 feet per second. Reduce the depth to 1 foot, and that part of the loss of velocity due solely to the change of form in the vertical curves will be by our formula about 0·2 ft. If the velocity were 1·5 ft. per second, the corresponding reduction would be about 0·15 ft. Reducing the width in the same proportion, namely to 32 ft., the part of the loss in velocity due solely to the change of form in the horizontal curves, is shown by the above expression to be about 0·15 ft. and 0·08 ft. respectively, for mean velocities of 4 ft. and 1·5 ft. Of course, the numerical values of such reductions vary according to the dimensions of the primitive stream; but that the amount indicated by this expression, deduced from the observations of MM. Darcy and Bazin, accords in general with the results of the study of vertical curves upon the Mississippi, is evident.

The following table exhibits the results obtained by applying the correction u to the indications of our formula for the observations of the last class (area of cross section less than 50 ft.) in the general table. The data in full, and the results of the Darcy-Bazin and Hagen formulæ, are repeated for convenience of comparison.

It will be noticed that the discrepancies of our formula, with the new correction term added, are slightly less than those of the Darcy-Bazin formula for their own data.

Measurements upon Very Small Streams, with Tests of Formulæ.

No.	Stream.	Original.		Cross Section.			Slope.	Observed Mean Velocity.	Discrepancy.		
		No	Series.	Area.	Wetted Perimeter.	Mean Radius.			D. B Formula.	Hagen Formula.	H. A Formula.
				sq ft.	ft.	ft.		ft.	ft.	ft	ft.
1	Feeder Chazilly...	1	37	9·5	9·9	0·96	0·000 792	1·234	—0·062	—0·072	—0·013
2	.....	2		14·9	12·3	1·21	0·000 808	1·667	+0·067	+0·193	+0·175
3	.....	3		19·4	13·8	1·41	0·000 858	1·815	—0·191	+0·208	+0·127
4	.....	4		22·9	14·7	1·56	0·000 842	1·998	—0·060	+0·314	+0·203
5	.....	1	38	9·3	9·7	0·96	0·000 957	1·244	—0·187	—0·106	—0·068
6	.....	2		14·1	11·9	1·18	0·000 929	1·703	0·000	+0·213	+0·174
7	.....	3		18·8	13·3	1·41	0·000 963	1·798	—0·252	+0·152	+0·025
8	.....	4		22·2	14·4	1·54	0·000 986	1·959	—0·255	+0·244	+0·121
9	.....	1	41	11·3	10·8	1·04	0·000 445	0·962	—0·087	—0·275	—0·163
10	.....	2		18·1	13·1	1·38	0·000 450	1·296	—0·091	—0·132	—0·079
11	.....	3		22·9	14·6	1·57	0·000 455	1·401	—0·112	—0·125	—0·111
12	.....	4		27·2	15·9	1·71	0·000 441	1·510	—0·106	—0·074	—0·087
13	Feeder Grosbois	1	47	11·8	10·8	1·09	0·000 464	0·820	—0·295	—0·455	—0·348
14	.....	2		17·2	12·5	1·38	0·000 450	1·326	—0·047	—0·102	—0·042
15	.....	3		23·0	14·1	1·63	0·000 479	1·434	—0·172	—0·134	—0·125
16	.....	4		26·8	15·7	1·71	0·000 493	1·683	—0·017	+0·070	+0·041
17	.....	1	48	10·1	10·2	0·98	0·000 555	0·984	—0·157	—0·262	—0·162
18	.....	2		15·4	11·8	1·30	0·000 555	1·480	+0·059	+0·045	+0·091
19	.....	3		20·9	13·4	1·56	0·000 525	1·575	—0·047	+0·018	+0·083
20	.....	4		25·9	14·1	1·71	0·000 515	1·746	0·000	+0·122	+0·214
21	.....	1	49	10·9	11·4	0·96	0·000 280	0·886	+0·155	—0·194	—0·023
22	.....	2		17·1	12·9	1·32	0·000 275	1·336	+0·321	+0·030	+0·175
23	.....	3		24·2	15·5	1·57	0·000 246	1·362	+0·243	—0·015	+0·083
24	.....	4		30·8	17·3	1·78	0·000 275	1·447	+0·148	—0·027	+0·060
25	.....	1	50	11·8	11·3	1·05	0·000 310	0·817	—0·065	—0·353	—0·205
26	.....	2		18·0	12·7	1·42	0·000 299	1·200	+0·051	—0·086	+0·034
27	.....	3		25·4	15·4	1·65	0·000 330	1·296	—0·002	—0·204	—0·033
28	.....	4		32·0	17·3	1·85	0·000 330	1·411	—0·085	—0·157	—0·138
80	River Schwarza...	1		46·7	58·3	0·80	0·009 000	2·528	—1·186	+0·737	—0·106
82	Hockenbach, I–II			10·5	12·0	0·87	0·000 778 3	1·440	+0·263	+0·198	+0·201
83	" II–III			10·3	11·8	0·88	0·000 796 6	1·463	+0·259	+0·209	+0·252
84	Speyerbach.....			30·2	19·7	1·54	0·000 466 6	1·814	—0·297	+0·360	+0·201
85	Huebeograben....			3·8	6·4	0·59	0·001 300 0	1·424	+0·360	+0·310	+0·479
	Total.....	33						48·139	5·731	6·156	4·388

In fine, then, we have the following table exhibiting for natural channels the absolute and relative accuracy of the Darcy-Bazin and Hagen formulæ, and of our Mississippi formula, including the new term for width correction.

This table exhibits in a striking manner the extended applicability of the Mississippi formula. It is clear that in order to truly represent the flow of water, every possible cause of variation must be taken into account. In our formula this has been scrupulously done. The effect of the slope, the area of cross section, the perimeter and the width upon the velocity of the exterior layer of the fluid; the effect of variations in velocity and in depth, and now—thanks to the new

Final Analysis of the Grand Table of River Data.

Areas of Cross Section, varying between	No. of Obs.	Sum of observed Velocities.	Sum of computed Velocities.			Sum of Discrepancies.			Percentage of Discrepancies.		
			D. B. Formula.	Hagen Formula.	H. A. Formula.	D. B. Formula.	Hagen Formula.	H. A. Formula.	D. B. Formula.	Hagen Formula.	H. A. Formula.
Sq. ft.		ft.	ft.	ft.	ft.	ft.	ft.	ft.			
200 000 and 10 000	19	89·914	80·709	92·058	93·405	22·123	8·124	5·451	24·6	9·1	6·1
10 000 and 1 000	35	116·889	120·286	112·419	121·912	14·108	18·447	11·438	12·1	15·8	9·7
1 000 and 50	11	27·250	29·171	22·199	26·743	3·899	5·497	2·061	14·3	20·2	7·5
Less than 50	33	48·139	49·814	47·529	47·168	5·731	6·156	4·388	11·9	12·8	9·1
Total,	98	282·183	279·980	274·205	288·328	45·861	38·224	23·338	16·3	13·5	8·2

and valuable experiments—in width also, upon the transmission of these exterior resistances through the fluid mass, have all been carefully considered. It is gratifying to find from this large table of data, less than one-third *of which was available in studying the subject and in framing the equations*, that the investigation has resulted in a river formula which for slopes not exceeding 0·009 reduces the average percentage of error in computed mean velocity to about eight per cent., or nearly to the limits of error in careful actual measurement;*

* See second edition of the Lowell Hydraulic Experiments, by Mr. James B. Francis, Civil Engineer in Charge. It is a standard authority, giving the results of elaborate experiments, both with hydraulic motors, and in gauging the flow of water over weirs, through short open rectangular canals and through submerged orifices and diverging tubes. The gauging of the open canals was done by floats, consisting of cylindrical rods so ballasted as to remain vertical and extending from the surface nearly to the bottom. They were well distributed across the canals, which were from 8 to 9 feet deep and either about 13 or 26 feet wide. All the details of observation and computation were so arranged as to secure the highest attainable accuracy. The computed results, corrected by an original formula for the depth not covered by the rod, were checked by an exact weir measurement, and the liability of the method to error was thus closely determined. The following extracts give useful information in this connection: "The observed velocity at the same part of the section is constantly varying; this is not due, in any sensible degree, to errors of observation, but to actual changes in the velocity, due to the unstable condition of the current." From seven experiments made in calm weather, Mr. Francis infers "that any single measurement is liable to be erroneous to the amount of one per cent. or perhaps rather more." From seven experiments made in a strong wind, he decides "that the irregularities in the results of the measurements were much greater when the wind was blowing strongly than when it was calm, or nearly so. The extreme variation in the seven experiments is nearly five per cent." The liability to error in gauging rivers must of course considerably exceed these limits.

and this, too, whether the stream is a river like the Mississippi or a canal feeder—always provided that *its bed is of earth, and of a roughness of surface and regularity of section usual in straight portions of rivers of corresponding slope.*

MM. Darcy and Bazin possessed no data upon very large rivers, nor upon those whose slopes ranged through extended limits. For this reason they were able to represent by a simple "formula of interpolation" the material at hand. Expressed in English feet, it can be put into the following convenient form for use. Had more extended data been available, it would doubtless have undergone extensive modification—especially in relation to the slope, which for natural channels, at least, should not enter to a higher degree than the fourth root. It is probable that for artificial beds, a higher power may correctly represent observation; but in natural channels the resistances due to inequalities of cross section rapidly increase with the mean velocity, and accordingly we find that slight variations in slope produce great effects upon the discharge when the slope is very small, and have little influence when it is great. The law of change exacts a small fractional exponent for this variable.

$$v = r \sqrt{\frac{1000\, s}{0{\cdot}08534\, r + 0{\cdot}35}}$$

M. Hagen had access to much more of the data in the foregoing table than did either M. Bazin or ourselves; but groping for an empirical expression rather than seeking a formula grounded upon scientific principles, he has failed to frame one of general applicability. His expression is:

$$v = 4{\cdot}39 \sqrt{r} \sqrt[6]{s}$$

To each of these formulæ, the language used by M. Bazin respecting an equation of M. Darcy is strictly applicable: "It represents very well the results of the experiments from which it has been deduced; but, like every empirical formula, it cannot be employed with certainty beyond the limits within which it has been obtained." For general application, they are evidently too simple to prove exact, since many causes of variation in flow are not represented.

To the three classes into which MM. Darcy and Bazin divide *artificial* channels, their formulæ—differing only in the numerical values of the constants from that for natural channels given above—seem to

apply. It would be interesting to determine whether still closer accordances with observation might not be obtained, by employing the same analysis with these classes of channels as was used in deducing our river formula. For this purpose, it would only be necessary to follow the rigorous method above indicated. Since artificial streams are necessarily very small, it would be requisite first to study, in the manner already explained, the numerical values of the constants in the expressions for b and b'. Possibly a function dependent upon the nature of the bed, introduced into the equations for these variables might render a single formula applicable to all classes of uncovered artificial channels.

Our formula is too complex for convenience in computation, when applied to small streams; and I have therefore thought it desirable to prepare the appended table to facilitate its use. The following equations—of which the first represents the formula in full, and the second as simplified for use with the table—render it easy to understand the proposed application. For streams larger than 50 feet in cross section, the term involving M′ may be dropped; and for large rivers exceeding a dozen or twenty feet in mean radius, M—but not $\sqrt{\text{M}}$—may be neglected.

The symbols have the following significations; all expressed in English feet:

v = mean velocity.

v' = value of first term in the expression for v.

a = area of cross section.

p = wetted perimeter.

W = width.

r = mean radius or $\frac{a}{p}$

s = sine of slope of water surface, corrected for bends. Its numerical value is found by dividing by the total distance between the level stations, measured on the middle line of the channel, the total fall between them, after subtracting the value of h' in the following formula for bend effect, in which N represents the number of angles, 30° each, of the mid-channel line. $h' = \frac{v^2 \text{N} \sin^2 30°}{194}$. Of course, the method of successive approximation must be used in finding the value of v in this formula.

b = function of depth entering expression for sub-surface curves,

or $\dfrac{1{\cdot}69}{\sqrt{r}+1{\cdot}5}$

$$v=\left(\sqrt{0{\cdot}0081\,b+\left(\frac{225\,a\sqrt{s}}{p+\mathrm{W}}\right)^{\frac{1}{2}}}-0{\cdot}09\sqrt{b}\right)^2-\frac{2{\cdot}4\sqrt{v'}}{1+p}$$

$$v=\left(\sqrt{\mathrm{M}+\left(\frac{225\,a\sqrt{s}}{p+\mathrm{W}}\right)^{\frac{1}{2}}}-\sqrt{\mathrm{M}}\right)^2-\mathrm{M}'\sqrt{v'}$$

If it be desired to determine any element other than the mean velocity, for a very small stream less than 50 sq. ft. in cross section, the new subtractive term containing M′ should be used in connection with the formulæ given on pages 313, 314, Vol. XLV, and a method of computation by successive approximations must be employed.

Table to Facilitate the Application of the Humphreys-Abbot Formula for Mean Velocity.

r	M	$-\sqrt{\mathrm{M}}$	p	M′	Log. M′
1	0·0087	0·0930	5	0·400	9·602060
2	0·0073	0·0855	6	0·343	9·535294
3	0·0065	0·0803	7	0·300	9·477121
4	0·0058	0·0764	8	0·267	9·426511
5	0·0054	0·0733	9	0·240	9·380211
6	0·0050	0·0707	10	0·218	9·338456
7	0·0047	0·0685	12	0·185	9·267172
8	0·0044	0·0666	14	0·160	9·204120
9	0·0042	0·0649	16	0·141	9·149219
10	0·0040	0·0634	18	0·126	9·100371
12	0·0037	0·0610	20	0·114	9·056905
14	0·0035	0·0590	22	0·104	9·017033
16	0·0033	0·0573	24	0·096	8·982271
18	0·0031	0·0558	26	0·089	8·949390
20	0·0029	0·0544	28	0·083	8·919078
30	0·0024	0·0494	30	0·078	8·892095
50	0·0019	0·0437	50	0·047	8·672098
100	0·0013	0·0369	100	0·024	8·380211

Chemistry, Physics, Technology, etc.

DECAY AND PRESERVATION OF TIMBER.

I. *Theory of decay in wood.*—It is theoretically claimed that the principal inherent action producing decay in wood are:

Firstly. The decomposition of the albumen contained in the sap part, and from this decomposition results a poison which being in juxtaposition with the heart part, induces speedy decay in it.

Secondly. Slow oxidation or spontaneous combustion, which may go on in both the sap and the heart parts, more particularly in the latter.

Thirdly. It is added by some to the first two postulates, that "air and water are essential to the decay of wood."

II. *Experience in respect to wood, untreated, and treated with antiseptics.*—While I am not disposed to doubt the first two points of theory just quoted, I am nevertheless constrained to deny the third, and to believe on the contrary that air and water—especially fresh water—do essentially preserve untreated timber from decay. The stubborn fact of green and seasoned timber for constructions being put under water and there remaining for a century, subject also to air, which always exists more or less in agitated water, without the slightest sign of decay and then found as strong as ever, is sufficient to overthrow the third point of this theory. And but for the sea-worms and barnacles, the same experience holds for untreated timber under sea or salt water.

I have known oak and pine beams, encased in solid brick masonry where hardly any air or moisture could reach, perfectly rotten after eleven years of such imprisonment.

Nor can it be maintained that all kinds of untreated wood exposed to soil, air and water will very speedily decay. The speediness of decay of timber thus exposed will depend upon the kind of wood, the particular acids or salts in the soil, the climate where the timber is to be used, and the thickness of the sticks. To illustrate this, it is only necessary to adduce a few facts which have come under my own observation, also, some well authenticated circumstances coming under the observation of other engineers of constructions.

In houses of the old dilapidated town of Chagres, lignumvitæ mud-sills were found, after lying seventy-two years upon the ground, per-

fectly sound. This induced the engineers of the Panama R. R. Co. to replace their first ties, which were of the very best Georgia pine, and which lasted not to exceed three years, with lignumvitæ brought from Darien, at a cost (in 1855) of $1.00 per tie. The same Georgia pine taken to a northern climate would have lasted as railroad ties seven years, at least, before requiring renewal.

Red cedar heart in its natural state as fence posts and mudsills has lasted fifty years in the clay and gravelly loam in northern climates without appreciable decay, but in strong lime soil it yields in less time; while white or yellow cedar will last only from fifteen to twenty years before it will become decayed in a similar exposure and soil.

In the rich bottom lands of Wisconsin, I saw the original massive white oak trunks exhumed as it were from beneath the mucky ground, where they had been upturned by an ancient tornado, and timber made from them in 1842; the wood was then perfectly sound after an age of centuries, and the timber made from them, used in a construction under cover, is at the present time as sound as ever. Those oaks must, judging from the age of the trees succeeding them and growing among and over their prostrate bodies, have lain there for centuries; and yet in the very same neighborhood the same kind of oak apparently cut from the living trees, lasted as fence posts in a limy clay soil only ten years, untreated.

The untreated "redwood" of California, in contact with soil from volcanic debris, I found, on testing its durability, quite as lasting as our red cedar, though it is by no means the same kind of wood. It is weak and brittle; neither is it the same kind of wood as the "mammoth trees" of that State.

I have found our northern red cedar, treated with the old Kyan process, an infusion of corrosive sublimate, after twenty-two years' exposure lying on a slope of strong limy soil, to have gone to decay, especially the lower ends of the sticks, and kyanized white oak of Michigan, resting upon the same kind of dirt, dozed and rotted twenty years after the treatment.

Chestnut railroad ties grown upon the barrens of Maryland, kyanized and laid upon a limy soil some miles north of Baltimore in 1838, I saw tested eleven years afterwards and then perfectly sound, and more solid than when laid; while those of the same kind of wood, untreated, but laid at the same time in the same kind of soil and exposure with the treated ones, lasted only seven years before they required renewal.

This experiment of kyanizing timber was the first, I believe, ever practiced in our country. Ties enough were treated for one mile of track, costing twelve and a half cents per cubic foot of timber. The process, however, was so unhealthy, salivating all the men, it had to be abandoned It would be worth while to ascertain if those kyanized ties are yet sound. At that time the untreated ties cost only fourteen to sixteen cents.

The original growth of white soft pine of New England, in fence boards untreated and not touching the ground, has been known, after an exposure of more than fifty years, free from all signs of decay, while heavy sticks of timber of the same wood and similar exposure, were found much decayed in a shorter period. White spruce and red hemlock of that part of our country I found, on examination, untreated, would only last, the former eleven years, and the latter nine years, while white hemlock is more durable than either.

In my experience, going back to 1839, in respect to harbor pier works on our fresh water lakes, I have found all kinds of timber grown in the vicinity of these waters, and used in the constructions after having laid forty years under water, as sound and strong as when put in fresh from the stump; and I have not the slightest doubt of their lasting, so far as decay is concerned, ten times forty years longer. And untreated white oak and white elm piles, which must have been driven at least forty years, I have found perfectly sound all below and for one or two feet above water, their tops being injured only by abrasion. In these waters there is no need of treating by any antiseptic the timbers to be placed under water.

But for all the horizontal-side, end and tie timbers above the first foot above water, the experience is quite different. As a general rule, I have found these timbers to show decay in seven years after being laid without treatment; and yet many have lain from twelve to fifteen years; but then they have become so rotten as to be blown away by the winds or torn off by the waves. Without treatment, therefore, by some antiseptic we cannot rely upon the timber in these superstructures lasting more than seven years without need of renewal.

In the pier superstructures, we have used chiefly white and hard or red pine and white oak. The vast amount of beautifully shaped timber for the sizes we need, but deemed as too inferior in quality for these superstructures, growing, however, in the vicinity of the lake shores, such as hemlock, white cedar, bass, fir, white and black ash, hickory, white elm, beech, sycamore, etc., etc., are utterly ignored.

An antiseptic that would materially, say double or triple, the period of decay in these would enable us to bring them into use, at a cost for the untreated timber considerably below that of pine and oak.

The ancient Egyptians must have known of antiseptics for preserving wood. Their old wooden coffins, after 2,000 years, have been brought to light; and a gentleman of much experience in the causes of decay and means of "preservation of wood," has informed me, he "has seen several of these split to pieces, and that the wood (sycamore) was perfectly sound and strong; the wood seemed to have been impregnated with a bituminous substance. The coffins were 'dug outs' from solid blocks of the wood, leaving a hole in the top to insert the corpse, and having a lid carved and ingeniously fitted to enclose the aperture." Now sycamore, as we know it, untreated, is not a very lasting wood. Whether the lost art is to be recovered by the use of modern antiseptics remains to be seen by future generations.

Worms in Wood on Land and in the Open Air.—There is a destructive attack by these upon wood of the trees which have been cut into logs, out of which timber and lumber are to be manufactured at the mill.

The trees are generally felled and immediately cut into lengths suitable for these logs in the winter, and either hauled to the mill during the same winter or rafted to it early in the spring and sawed during the same spring and succeeding summer. In this way the eating by the worm is in a great measure avoided. But if the logs of almost any kind of wood are allowed to lie over the summer on the ground, they almost invariably become eaten, unless they are "drossed," which means, to hew off their bark. Peeling the bark of the hemlock in June for tanneries, will prevent the worm in this kind of wood.

If the season, however, is very wet and cold, logs with their bark on are less liable to attack where they lie over; and if they are "boomed," or put into a "log bay" of fresh water, they are preserved from this kind of worm, unless the eggs of the larva are laid in the logs before they can be put into the water, in which case the larva are known to develop into the living worm in six months after sawing and sticking up the stuff, which, though apparently free from the worm when piled, soon becomes greatly injured, as many a pile of supposed valuable timber has shown.

When a thrifty tree, however, is overturned by the roots and, after dying, cut into saw-logs or hewn, no worms will be found in the wood.

Some of the very best lumber comes from wind-falls after the trees have been dead for years, taking care, however, not to sever the rooty mass from the trunks while green. These facts led to the explanation of the manner in which these worms are produced in saw-logs and green timber recently felled by the axe. A small insect easily penetrates by the ends of the green log along through its whole length in the palatable juices between the dark and sap wood and deposits her eggs, which very rapidly develop into eating worms. No doubt there are various kinds and sizes of these preying upon wood, and among which may be classed the ants, which are so destructive to wood in tropical climates.

A windfall, with its up-turned roots having earth attached, affords no access to the insect; and when the green logs are "drossed," there is no bark shelter for the insect which dreads the water so much that it will not enter the logs after an immersion in fresh water.

It seems to me that if the lumber manufacturer has the ill luck of being compelled to allow the green logs to lie over on the ground, the besmearing of the ends with some cheap bad smelling paint might prevent the access of the insect.

Worms in Wood under Sea-water.—These, I have observed, on our sea-coasts, seldom work upon piles and dock-facing timbers, except in those parts standing between half ebb and half flood tides; in the space between these two planes, however, their operations are indeed wonderful and dreadfully destructive. On some of the European coasts, I think they range in their attacks from extreme low to nearly high tide.

It is not very many years since it was believed these worms could only exist in the tropical climates, and that they were only known in cold climates by being brought in vessel bottoms. But this was an illusion which experience has since dispelled.

As far east as Castine Harbor, Me., they began destroying piles and other dock timbers of the best white oak, and so effectually did their work that renewals had to be made. It is believed they were introduced there from old worm-eaten vessels coming home and lying to the docks until the vessels no longer afforded substance for boring, then the worms forsook, and resorted to the piles and dock timbers. No oak has for years been used there for the renewals. Yellow pine is used, and as long as the resin remains in the wood, it is comparatively free from the worm; but after a few years, the resin becomes washed out, then the worms commence the havoc in good earnest.

In various places on our Atlantic coast from Maine to Mexico, and on our own Pacific coast, this annoying and costly evil exists. There, I have observed, no vessel or wood structure, except as high up as about where the fresh water and the tide water meet, is safe from this evil. The remedy of covering the exposed parts with the sheet copper is only effectual until the sheathing becomes punctured, torn, or abraded off, then the worms immediately enter.

In the bay of San Francisco, the worms are very active and produce great havoc. They bore deep into the piles and dock timbers, leaving hardly any part within their range unperforated, but the tubular track of one never pierces across the tube bored by another worm. Their instinct teaches them scrupulous respect for each other's way. In a period of less than four years they will destroy the piles. And there are worms that wield their mandibles with such extraordinary power as even to bore into solid rock.

In the lower part of the Sacramento river, just above where it enters Suisune Bay, the banks at low tide expose all along for one or two miles innumerable hard compact sand-boulder rocks. In carrying a military survey along these banks, I observed in hundreds of the rocks deep tubular holes of from one half to three-eighths inch in diameter, running straight in, some to the depth of eighteen inches. Every hole was lined with a perfect coating of beautiful white enamel as hard as glass. At the bottom of each hole there was invariably a worm found, who had bored for himself a habitation into the rock. These extraordinary mandibular worms, if not the same kind, are about the same size, I judged, as the smaller kind of salt water borers called *limnoria*.

The piles used in the San Francisco waters, are chiefly Oregon spruce and Oregon pine. An antiseptic that will preserve wood there will not fail to be favorably received.

I submit a tabular statement, A, of results of experiments in "creosoting" wood in foreign countries for preventing attacks of these worms, by which it will be seen at a glance how efficacious this has proved thus far. How much longer in the future it will hold their sharp mandibles in check, can only be known by future observations, which I trust will be made by those civil engineers from whose reports I have made up the table or by those succeeding to their places.

APPARATUS USED IN CREOSOTING TIMBER AT ST. CLAIR FLATS, MICH.

PATENTS OF SEELY & PELTON.

Accompanying Report of Genl. T. J. CRAM, U.S. Corps of Engineers, to the Chief of Engineers, U.S.A.

1871

Fig. 1.

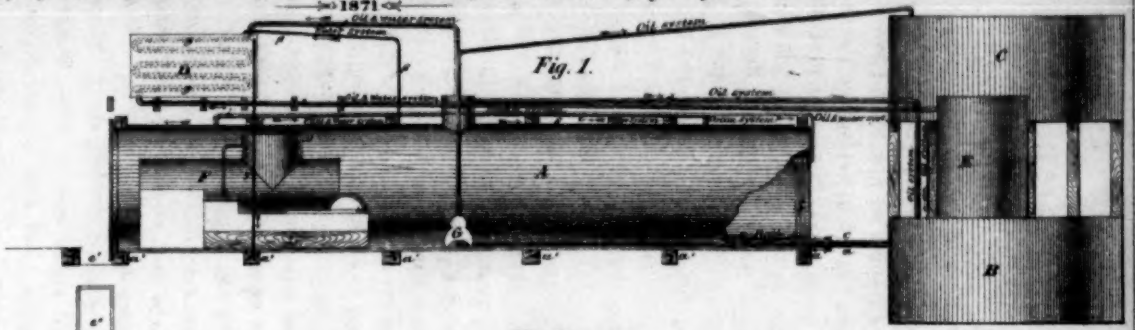


Fig. 2.

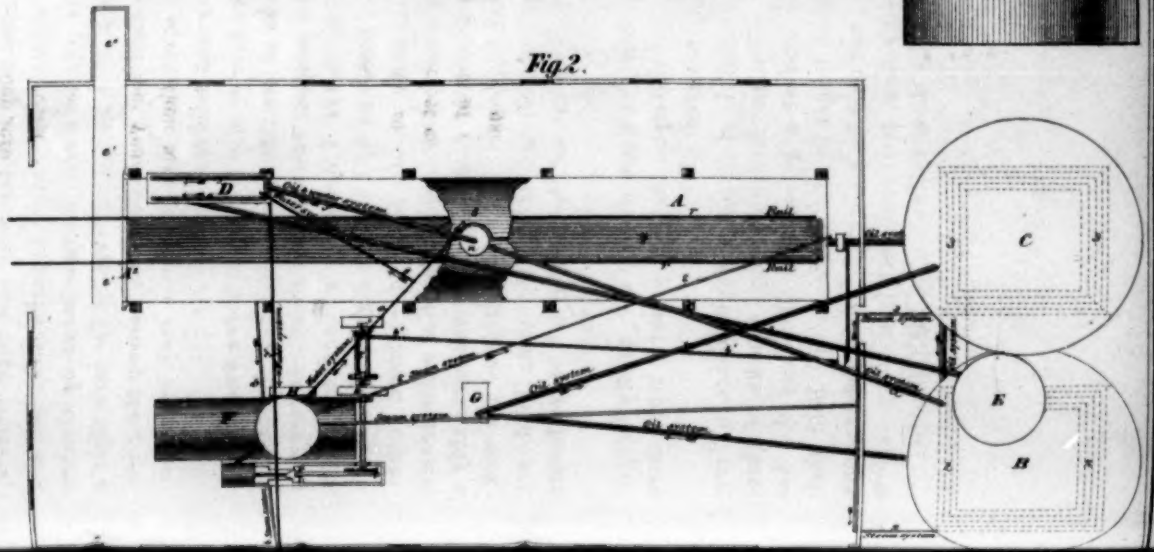


Fig. 3.

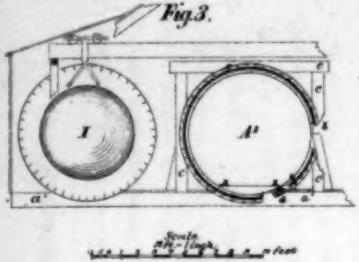


Fig. 4.

Fig. 5.

Fig. 6.

TABLE A.

Results of Creosoting Wood in Foreign Countries, to prevent attacks from sea worms, compared with results pertaining to the same wood, untreated.

Places of Experiment and Authority.	Kind of wood creosoted.	Period of years in use after creosoting.	Condition at expiration of that period.	Period the wood would have lasted uncreosoted before destruction by worms.
Ostend Harbor. L. Crepin, *Engineer, &c.*	Baltic Fir.	7	No attack. Sound.	2
Leith Pier and Harbor. Thomas Maclane, *C. E.*	Not Stated.	12	No attack. Sound.	3½
Docks at Monk-Wearmouth. A. Forestier, *Engineer.*	Yellow Pine.	20	No attack. Sound.	Not Stated.
Teignmouth. Mr. Brunel, *Engineer.*	Not Stated.	7	No attack. Sound.	Not Stated.
Grimsby Dock Adam Smith, *Engineer.*	Not Stated.	7	No attack. Sound.	3
Portland Breakwater. John Coode, *Engineer.*	Not Stated.	4	No attack. Sound.	3

At Leith Pier, the piles were dosed by using ten pounds of the oil, the cross ties and stringers seven pounds, and planks six pounds per cubic foot.

In France, Belgium and Holland, I learn, that from sixteen to twenty-six pounds of the oil, per cubic foot of the timber, was used for marine purposes formerly. Mr. George Shepard Page, who has extensively examined marine works in Europe, reports six to nine pounds, as now used to the cubic foot in sea-constructions, and says, "in no case has properly creosoted wood, employed to prevent the worm, failed to give complete satisfaction."

TABLE B.

Results of Creosoting Wood in Foreign Countries for Props in Collieries, compared with the duration without treatment.

Place of Experiment and Authority.	Kind of Wood Creosoted and Used.	Period of Years in Use after Creosoting.	Condition at expiration of that period.	Period the Wood lasts without Creosoting.
South Durham Colliery. Adam Hackworth, *Overseer.*	Not Stated.	15	Perfectly Sound.	¾ of a Year.
Tanfield Moor Colliery, James Joicy & Co.	Larch.	7	Perfectly Sound.	1½ Year only.
Mickley Colliery. Matthew Liddell.	Larch.	14	Perfectly Sound	6 Years.
	Scotch Fir.	14	do. do.	4 Years.

The larch here spoken of is, I believe, similar to our American bald spruce or tamarack.

TABLE C.

Results of Creosoting Wood for Railroad Ties in Foreign Countries, compared with the duration of the same wood Uncreosoted, for Ties.

Name of Railway and Authority for the Experiment.	Kind of Wood Creosoted and used for the ties and longitudinal timbers.	Period of Years in use after creosoting.	Condition at expiration of that Period.	Period of duration for the same purpose, uncreosoted.
Manchester & Crewe Railroad. *Building News*— July 5th. 1870.	American White Fir.	32	Perfectly Sound.	Not Stated.
Cologne & Minden Railroad. G. Freme, *Inspector.*	Not Stated.	12	Perfectly Sound.	4
India Railroads. Mr. Burt.	Not Stated.	20	Perfect y Sound.	Not Stated.
Stockton & Darlington. Thomas Summerson, *Inspector.*	Yellow Pine.	26	Perfectly Sound.	6½
Yorkshire & Lancashire Railroad. R. J. Badge.	Not Stated.	24	Perfectly Sound.	Not Stated.
Midland & Great Western Railroad. James Price.	Red Baltic Fir.	9	Perfectly Sound.	Not Stated.
Great Eastern R. R. Samuel Dawson, *Sup't.*	Scotch Fir.	16	Perfectly Sound.	Not Stated
Belgium Railroads. Minister of Public Works.	Red Pine, Oak, Beach.	19	Perfectly Sound.	Not Stated.
Austrian, French, Prussian and Russian Railroads. George Shepard Page.	Baltic Fir.	20	Perfectly Sound.	4

It is to be observed, that at the expirations of the periods expressed in the third column of A, B, C, the timber which was treated is reported perfectly sound; there is no evidence showing how much longer it will last; and I can find no evidence of any which has been creosoted having yet decayed, or having been attacked by worms.

Among the quoted authorities, I gather from those who have given recent attention to the subject, that from seven to nine pounds of creosote oil per cubic foot of timber used for railroads and other purposes on land, is the proper dose. It is to be regretted that in none of the foregoing experiments, the cost of creosoting per cubic foot, the original cost of the untreated timber, nor the cost of the labor of con-

struction per cubic foot, is given. The only data I can obtain from foreign reports on either of these points, is from one on the Dublin and Drogheda R. R.; and I deduce from this data, that the creosoting of the ties costs six cents per cubic foot of timber with seven pounds of "crude" oil per cubic foot. Without all the items just mentioned, it is impossible to solve the problem of the measure of the economy of creosoting in foreign countries.

Mr. Page, whose report bears date 28th May, 1870, made the subject of a specialty recently in European countries. He says, that "the creosoted timber for railroad constructions has not yet failed from perfect soundness. * * * Wood for marine constructions, railroad constructions, fences, telegraph and hop poles, and for uses in coal and iron mines, is almost universally creosoted; and that treated timber is the rule; and untreated timber the exception. * * Another effect is observed; iron spikes, nails, bolts, etc., inserted in creosoted wood are protected effectually from rust. * * * And crude creosote oil is almost universally used in the process all over Europe."

(To be continued.)

CHEMICAL AND SANITARY REPORT UPON THE PASSAIC RIVER.

Made to the Board of Public Works of Jersey City.

By Professor Henry Wurtz.

(Abstract, made and communicated to this Journal, by the Author.)

Hoboken, *March* 1*st*, 1873.

Gentlemen,—I have been charged by your Honorable Board with the investigation of the waters of the Passaic, with a view to determine the sanitary questions regarding contamination by sewage and other causes.

All the analytical results herein reported were obtained by the personal labor of the undersigned.

Collection of the Samples for Analysis.—At the outset of the investigation, and on his first visit to your Pumping Works at Belleville, your reporter recognized a source of contamination to the stream which has hitherto been strangely overlooked. It seems incredible that it should be pointed out for the first time here; but, in a sanitary view, it clearly involves the most important questions connected with this stream, and its relations to the rapidly increasing town populations that look thereto for their supply of a necessary of life.

The source of contamination referred to is the flow into your pumps, during rising tides at least, of water which must have received the drainage of the populous city of Newark.

Samples were therefore so collected at Belleville as to enable this new question—regarded as the most important one that has arisen—to be tested analytically; namely, by taking the water at extreme high tide, to represent the maximum of contamination from Newark; as well as at extreme low tide, to represent water contaminated only with matters brought down by the river itself and its affluents above Belleville. An additional sample was taken from the Receiving Reservoir.

It providentially happened that it was possible to procure these samples after an interval of dry atmosphere, of at least eight days (October the 10th, 1872, being the date); thus giving us the important assurance of absence of dilution of the river with rain. Since then there has been no occasion equally favorable; the incessant and almost unexampled alternations of rains, snows and thaws, having kept up in the river a continual condition, more or less, of flood. Samples were afterwards obtained from above the Passaic Falls, from the discharge of two of the main sewers of Paterson, and from the river itself below the discharge of all the sewers of importance, off the Straight Street Bridge, Paterson.

In connection with the sewers, other instructions received from your Honorable Board were, as far as practicable, carried out, relating to inquiries into sources of possible contamination of the sewage waters by mineral and metallic matters, from the different dye works and factories.

The samples were sealed securely, with pure paraffin, at the water works (in the presence of your Chief Engineer, Mr. Culver), and after being packed in an inverted position, were transported to the laboratory of the writer in Hoboken.

Preliminary Preparation of the Samples.—The bottles were placed, without unsealing, in a light room without fire, which, because surrounded by other rooms constantly warmed, remained above freezing even during the intensity of the past winter. The primary object was to obtain such *sediments* as might deposit, including possible products of germination and growth of vegetable spores. In about one month (November 14th), the samples of water, having then become perfectly limpid, though of a pale brownish tint, were carefully pipet-

ted off from the sediments, the latter collected, dried at an extremely gentle heat, weighed, and reserved for examination as below.

The Methods of Analysis.—The older methods of analysis of potable waters, by which it has been customary to determine with great precision the actual quantities and relative proportions, per stated volume, of all the different acids and bases belonging to the purely "inorganic" constituents, have, within a decade past, fallen into disrepute and even desuetude among some chemists who have been active in the advancement of sanitary chemistry; and a far greater importance now attaches, among these, to the so-called "organic" constituents, or rather those assumed to be peculiarly of organic origin. This later school of chemists and sanitarians has in many cases abandoned the practice of determining anything regarding the solid so-called "mineral constituents" more than their simple sum total, after expelling all volatile matter.*

There is, on the other hand, another school of water-analysts, which adheres to older ideas, and, as the writer believes, exaggerates much the difficulties and uncertainties its adherents attach to most of the more recent methods of detecting and determining constituents present in quantities too small to be weighed—a class of constituents comprising many of the products of putrefaction and decay. This school goes so far in the other direction, as to reject the modern "microchemical" methods, as of no practical value.

From this conclusion, and from the general views of both the schools of chemists referred to, the present writer's own experience forces him to dissent; and, in brief, his own belief rests on the middle ground between these two schools; and, in this investigation, he has deemed it essential to apply, as thoroughly as possible, *both* the older and newer schemes of analysis.

Special Observations on Methods.—The residues left by all the samples of water on evaporation in white porcelain, were of an orange buff, approaching to salmon-color, while those left in platinum dishes were gray in color; and all, on heating, turned black, with a strong "peaty" odor, or at least an odor recalling strongly that of peat smoke. This odor, however, is of little value in itself as an indication of the character of the volatile matter present; but subsequent tests proved the presence of one or more of the peaty acids. The

*The highly valuable manual on Water-Analysis, by Wanklyn and Chapman, is an example of this, and I fear has done much harm in this direction.

incineration was very difficult, more like that of animal matters; and at the point of temperature required to form a white ash, a slight fume was often seen, though too slight to allow its character to be determined. The ash was nearly white, and effervesced slightly with acids, dissolving in muriatic with a distinctly yellow color, indicative of iron.

In addition to the samples from Belleville, it was thought important to take the opportunity to obtain the *average* composition of the water for the winter months, just as delivered and used by consumers, sediment and all, from the service pipes in Hoboken. In one case, during twenty days, as much as twenty quarts of the water were concentrated in a platinum dish on a water-bath, the object in this particular case, as well as in one other, having been to determine the ammonia, a drop of sulphuric acid being therefore added at the outset. It is to be remembered that these results on the hydrant water (reported in the fourth columns of the two tables of analyses given below), relate to an unusual winter period, during which the stream was more or less in continual flood.

Within a few years some European analysts have been active in devising new methods of discovering and determining substances which, though often occurring in waters in proportions justly termed micro-chemical, are nevertheless widely believed now to be of vital importance in a hygienic view.

It appears appropriate and requisite that a few specific though brief paragraphs (which may be more especially interesting, nevertheless, to readers of chemical attainments) should be given to an enumeration at least of the following methods, which were submitted to preliminary examination, and some of which were since made good use of in this research.

The Forchhammer-Condy Permanganate method; with the modifications recommended by Angus Smith, in whose high opinions of the real value of this method, when used understandingly, the writer must largely concur, though he has spent comparatively little time in actual work with it.

The Nessler-Hadow method for ammonia; which, as all chemists now familiarly know, is beyond all price or appreciation, in all chemical analysis, that for sanitary purposes included. To illustrate the extraordinary value of this Nessler-Hadow micro-chemical method, and the enormous stride in advance marked by it, it may here be added that in the evaporation before referred to, of twenty quarts of

hydrant water with acid, occupying twenty days, an attempt made to determine ammonia in the residuum, by common alkalimetry, failed altogether. In another parallel experiment, however, involving considerably less time and material, no less than five well-concurrent determinations were made upon the result of distillation with alkali, and three times as many more might have been had. The average figure arrived at is given below—0·005 grain of ammonia per gallon. The failure of the ordinary volumetric methods is here clear enough when we consider that the whole five gallons concentrated contained but one fortieth of a grain of ammonia.

The method for nitrogen acids, founded on reduction to ammonia by a metal, and then the Nessler-Hadow method. Schulze's improvement of using metallic aluminum in alkaline solutions, was found valuable; but the writer has found it far preferable to use, in addition, clipped iron wire, which, while hastening the operation by voltaic action, also subsequently prevents explosive ebullition, and bursting of the retorts. [It may convey to your Honorable Board some idea of *one* of the difficulties of this kind of investigation, to add that each repetition of the determinations of nitric acid here reported, and they were many, required alone at least one day of hard and anxious work and watching, and that before the discovery of the above safeguard, a dangerous explosion, involving damage to property, had occurred.]

The volumetric method for the determination of chlorine, with standard solution of silver and chromate of potash, which has been so highly lauded by some chemists, failed altogether in the hands of the writer, and he had to abandon it.

The Alkaline Permanganate method, for "albumenoids" or Proteine bodies of Wanklyn and Chapman. This method, which is less understood, probably, than any of the others mentioned, has been tested with some care; at first with the unsatisfactory results reported by some other chemists, and at last with some degree of satisfaction. Details cannot be entered into here. It is certain that W. and C. proved the existence of some form of nitrogenous matter in potable waters (previously freed from ammonia), which is convertible into additional ammonia (at least in part) by distillation with their new reagent. They also show similar results with albuminous matters, and with the usual immediate products of their metamorphoses, and it is hard to see what *other* substances could get into fluviatile and many other waters, that could give ammonia in this way. It is on these grounds that the writer has provisionally accepted their views and

their methods, and put the results into his tables of analytical results. As Dr. Angus Smith prefers the term proteine to albumen, in this case, it has been used here also. As the rule of Wanklyn and Chapman is to consider ammonia thus found to represent ten times as much "albumenoid," the figures in the table stand for but one tenth as much ammonia.

New Tests of Oxygenation and Rate of Aeration.—The writer has the satisfaction to announce here that, in the progress of this work, he has found new and valuable microchemical tests for potable waters, as to both the existing degree of aeration (or impregnation with free oxygen) and the rate of absorption of aerial oxygen; which he believes will be of especial value in determining the questions that have arisen regarding the Passaic water. Eminent chemists and sanitarians are agreed upon the important bearing of this ingredient (free oxygen) in potable waters. It has been considered as furnishing a measure of the freedom from liability to undergo fermentation or putrefaction; and it will scarce be denied by any that the most highly aerated water is, *ceteris paribus*, the safest. Oxygen is a consumer and destroyer, and in water destroys the enemies to human life therein. Indeed, it is too often the destroyer of human life itself, but with that we have now nothing to do. Streams flow through an atmosphere containing one-fifth of oxygen, but their precise actual contents, and their relative tendency to absorb, and their actual absorption of this agent (which latter is regarded as the measure of their ability to purify themselves), have heretofore been little more than matters of pure guesswork or conjecture. A reasonable hope may now be held that all this will soon be changed. Two or three of the curious and unexpected results of this new method may be mentioned.

Sewage which smells offensively of sulphuretted hydrogen still retains free oxygen, in traces readily indicated by this test.

Water may be *boiled* indefinitely, even boiled away altogether, but retain to the last traces of free oxygen.

Common salt expels all the oxygen from water (with certain precautions); the true explanation of its preservative power, etc., etc.

The Analyses.—All these figures are calculated on the basis of one United States gallon equalling 231 cubic inches of distilled water, each cubic inch weighing at 60° Fahr. 252·5 grains, making that gallon 58,327·5 grains. Some estimate it at a slightly different figure, but the difference is so trifling as to be immaterial.

Immediate Results of Analyses of Samples of the Passaic Water, expressed in grains and fractions thereof, per U. S. gallon of 58,327·5 grains.

Constituents of the Residues from Evaporation.	Settled Waters, taken October 10, 1872, at Belleville.			Analysis of 5 gals. of Unsettled Water, taken day by day from Hydrant in Hoboken. Winter average, December and January.
	Extreme Low Tide.	Extreme High Tide.	Receiving Reservoir.	
Sulphuric Acid	·6462	·7760	·6500	·2012
Nitric Acid	·1925	·3383	·2409	·2800
Carbonic Acid	·4100	·2000	·2500	·2880
Chlorine	·1505	·2923	·2163	·1520
Phosphoric Acid	·3800	·1780	·2001	·1202
Silica	·7910	·1120	·4000	·6344
Lime	1·0400	1·1974	1·1120	·8037
Magnesia	·3580	·4930	·4100	·3950
Potash	·0987	·2500	·2375	·1375
Soda	·1857	·4200	·3840	·2730
Ammonia	·0100	·0038	·0088	·0050
Peroxide of Iron	·1170	·0562	·0830	·0699
Alumina	·1660	·0956	·1322	·0868
Humic, or Peaty Acids (by difference)	·6007	·2638	·3612	·6136
Proteine Derivatives, or "Albumenoids"	·0437	·1066	·0810	·0467
	5·1900	4·7830	4·7670	4·1070

It will be observed that the amounts of volatile and combustible matter are not given, as is usual (these being duly classed as "organic matter"). In the case of this water, these are in large measure made up of nitric acid, carbonic acid expelled by the silica, and oxygen from the conversion of the sulphates into sulphides.

The Sediments.—Before the settled water was pipetted off from the sediment, in each case, a mark was made on the bottle at the surface of the liquid. The sediments were carefully detached from the glass in every part by bent rubber-tipped glass rods, washed with some of the same water into small beakers, from which, after settling again clear, they were transferred to weighed watch-crystals, dried at about 100° Fahrenheit, and weighed. The volume and weight of the water were then found by filling up to the mark from a calibrated measuring-cylinder.

Estimates of the Dissolved Saline Contents of Passaic Waters; founded on Analyses; expressed in grains and fractions thereof, per U. S. gallon of 58,327·5 grains.

Theoretical Constituents of the Residue from Evaporation.	Samples taken at Belleville, Oct. 10th, 1872. Thoroughly settled before Analysis.			Sample of 5 gal. from Hoboken Hydrant, taken gradually during 20 days in Dec., 1872, and Jan., 1873. Evap'd in platinum.
	Extreme Low Tide.	Extreme High Tide.	Receiving Reservoir.	
Sulphate of Lime	1·0985	1·3192	1·1050	·3420
Nitrate of Lime	·2923	·5137	·3288	.4252
Phosphate of Lime—tribasic.	·8300	·3847	·4368	·2624
Carbonate of Lime	·0617	·4545	·5681	·6545
Carbonate of Magnesia	·7258			
Chloride of Sodium	·2480	·4817	3564	·2505
Soda	·1190	·1652	·1993	·1402
Potash	·1190	·2500	·2375	·1575
Magnesia	·0124	·4930	4100	·3950
Lime		·0158	·0143	·0090
Silica	·7190	·1120	·4000	·6344
Hydrated Peroxide of Iron	·1375	0·657	·0970	·0817
Hydrate of Alumina	·2530	·1457	·2015	·1323
Humic or Peaty Acids (by difference)	·6007	·2638	·3612	·6136
Ammonia, free and combined (or as Urea)	·0100	·0038	·0088	·0050
Proteine Derivatives, or "Albumenoid" matters	·0437	·1666	·0810	·0467
Total Grains per U. S. gallon	5·2766	4 7906	4 8067	4·1300

These bases probably exist in the water in connection with the peaty acids, though perhaps also in part with carb. acid, which is expelled and replaced during the evaporation, by the peaty acids and the silica.

Sedimentary Deposits.

WATERS.	Extreme Low Tide Oct. 10, 1872.	Extreme High Tide Oct. 10, 1872.	Receiving Reservoir Oct. 10, 1872.	Hoboken Hydrant Nov. 1, 1872.
Amounts operated on, in grains,	61·729	62·470	60·186	58·327
Grains found, per U. S. gallon,	1·008	0·504	0·479	0·493
Prof. Horsford, October, 1851,		1·262		
Prof. Chandler, Hoboken Hydrant water of May 3, 1872				0·520
Total solid contents of unsettled waters; that is, the sum of these sediments and residues of evaporation,	6·198	5·287	5·246	

In the low tide water and receiving reservoir, appeared quantities of a green confervoid growth, characteristic of standing waters, much more perceptible on the watch crystal during dessication than at any time before. There was more of it in the low tide water. In the high tide sediment there was not the slightest trace of this perceptible to the eye.

Microscopic Examinations.—The general results of these were confirmatory of the above. The low-tide sediment was apparently made up chiefly of beautiful spicular and fibrous organisms, with bunches of their spores, doubtless belonging to the *confervæ* (fresh water *algæ*, frog-spittle). These were mingled with *very minute* translucent grains, looking like rounded sand, but more probably clay. In the reservoir sediment, there was more of the sandy looking matter and less of the organisms. Curious to say, however, though the search was made patiently for a long time, no trace of fibre or spore or anything organized whatever, appeared in the high-tide sediment. It was all a fine sandy looking mud. As all these waters had been kept under precisely identical conditions, and as the germs of this vegetation must have been equally dispersed through all of them, this is regarded as a most surprising fact. That the Newark sewage, or some other influence removes, between low and high tide, from the water, something essential to the germination and growth of vegetation, or else imparts something inimical thereto, are the only inferences to be drawn. Some of the green mass of confervoid fibre, removed from the edge of the watch crystal, of the low-tide sediment, and burned to ash on platinum foil, left a voluminous mass of white spiculæ, which, transferred to a platinum loop, fused readily to a transparent glass, and behaved generally like a mass of phosphates, but the quantity was too small for analysis. An attempt was made to determine, by incinerating, the amount of vegetable matter in the two sediments containing it, assuming that the mineral portion of each retained, when dried in air, about the same amount of water. The following are the results:

	Water per 100 of Sediment. (Estimated for 3 and 4).	Anhydrous Mineral matter, per U. S. gallon of water.	Vegetable Growth, in one U. S. gallon, in dry form.
1. High Tide,	20·00	0·403 grain,	*None.*
2. Hydrant,	23·38	0 368 "	(not determined).
3. Low Tide,	8·32	0·349 "	0·561 grain.
4. Reservoir,	15·01	0·255 "	0·152 "

The results in the last column of this little table must be regarded as among the most interesting obtained in the course of this investigation. The ash in each case contained iron, and had apparently about the same tinge of red.

Chemical and Sanitary Discussion of the Analyses.—These analyses furnish many points of interest in a purely chemical view, but it would be inappropriate to give much space to any of these, which have no *direct* sanitary bearing. Among the most important are the changes incurred by the water while being swept backward and forward past Newark by the tides. These are (see Table II):

A small increase of sulphuric acid, lime and magnesia.

A large increase of the nitric acid, chlorine, soda and proteine derivatives.

A diminution of the carbonic acid, phosphoric acid, iron, alumina, and humus compounds.

A large diminution of the silica.

The increase of nitric acid accounts for a large part (say half) the loss of carbonic acid. The phosphoric acid may very well be believed to have gone down with the alumina and iron, taking with it humus and some ammonia, and if, as seems probable, the silica is really held in solution by the humus acids, this would precipitate also. The loss of these ingredients *possibly* accounts for the fact that no confervoid growth whatever appeared in the bottle of high-tide water, as stated under the head of sediments.

Among these chemical points, of sanitary bearing, doubtless the most striking and important of all is the *increase* in the quantity of nitric acid in the water brought up by the rising tide past Newark, which increase is ·1458 grain per gallon. If this is regarded as having proceeded from albuminous or proteine bodies, it represents ·923 grain of these, which, added to the increase in the quantity of such bodies found directly, makes ·986, for simplicity say one grain per gallon, of dry products of putrefaction of albuminous matters, or say equivalent to 4 grains of decomposing egg-albumen per gallon.

If we suppose one *rotten egg*, weighing about 800 grains, to be beaten up with 200 gallons of low-tide water at Belleville, it might represent the *initial* effect of the Newark sewage, according to this rather unsavory calculation. What a rapid change is here shown to have occurred during the short run that the water has had, only be-

tween three and four miles, from New York up to Belleville.* The sewage matters have been constantly suffering a process of decay, slow combustion, or *eremacausis* (as it was called by Liebig), through the agency of the free oxygen held in solution in the highly aerated water pouring in every day from up stream; and, as the analyses further show, the residuum of the albumen or proteine derivatives, left from the Newark sewage, over and above those brought down from up stream, is but ·063 grain per gallon, and the whole amount in the high-tide but about one-tenth of a grain, equivalent, *if putrid*, to one rotten egg in 2,000 gallons of water. But it is unreasonable to suppose that this substance, whatever it may be, which yields ammonia with the powerful reagent of Wanklyn & Chapman, is still in a state of *putrefactive* change, or even *capable of such change*. Proteine bodies yield many products of metamorphosis which are highly stable. Dr. R. Angus Smith, in his writings on these subjects, refers repeatedly to waters answering to the Wanklyn-Chapman test, which are nevertheless incapable of putrefaction, and in one place infers the existence of some proteine body not susceptible of this change.†

The agency which effects this change, between Newark and Belleville, is that universal one which has long been studied by chemists, known as *nitrification*. Animal matters containing *nitrogen*, with *water*, *oxygen*, *alkaline* substances, and always *time*, are the conditions requisite to its progress. These analyses show the Passaic water to be an alkaline water, and we have present all the conditions for nitrification. The surprising circumstance is the short time apparently required.

The ·3383 grain of nitric acid in the high-tide water represents, when calculated as saltpetre, ·6327 grain thereof, and this, when calculated on the average daily flow of the Passaic water, is 90,400 lbs. of saltpetre per day (about 16,500 tons per year). About 40,000 lbs. per day of this is furnished by Newark, the other 50,000 by the rest of the inhabitants, both man and beast, oppidan and rural, of the 900 square miles of Passaic water-shed above. When we remember that this nitric acid represents but a fraction of the nitrogen of the effete matter from which it came, and that this nitrogen was itself

* On further consideration, since writing the above, it appears probable, however, that much of the water brought up by the high tides has run past Newark, back and forth, several times, and has had therefore a far longer course of flow than this. Still the *average* result should be the same. H. W.

† *Chemical News*, June 11, 1869, page 281.

but a small percentage of the whole, it is clear that these thousands of pounds of saltpetre must represent hundreds of thousands of pounds of effete matter cast daily into the waters of the Passaic. Some eminent chemists, particularly in England, have thrown doubts upon the conclusions drawn by others from nitrates, as indicating previous sewage contamination; claiming that nitrates may be washed out of older geological formations, and so on. In our present investigation we may cast aside this objection, as the Passaic basin contains nothing of the sort that could yield nitrates. All these must have come from the excreta of men and animals, the washings of barnyards, manured soils, etc.

We have now considered the bright side of the picture: let us look on the reverse. These samples of water were collected in cool autumn weather. Would analyses of the water in the heat of the summer show the same or like results, when the water is warm? The *warmer* the water, *the less oxygen it can absorb* under given circumstances. It is the oxygen dissolved *in the water* that does the work, and not that of the circumambient air, which can act but superficially.

In 1857, the great chemist, Bunsen,* published determinations of the capability of water to absorb oxygen at different temperatures. The following figures are extracted from his tables. One hundred volumes of water, *when saturated* with oxygen, contain at the temperatures specified respectively (reduced to Fahrenheit degrees, the intervals being 5° C. or 9° F. apart):

At	32° (freezing)	41°	50°	59°	68°	
	4·12	3·63	3·25	2·99	2·84	volumes.

As the temperature of the water during the summer heats ranges ten or fifteen degrees higher than the last figure (which is as high as Bunsen gave), we may assume as approximate that the power of the same water to absorb oxygen, *ceteris paribus*, is twice as great in the winter cold as in the summer heat. The qualification is used, because barometric pressure, and composition of the water itself, particularly the latter circumstance, have large, and even overwhelming influence, as has been ascertained by experiments with the new methods before referred to.

* Gasometry, Roscoe's edition, pp. 153 and 286.

In addition to this momentous fact, that water can absorb at the utmost but half as much oxygen per gallon in summer as in winter, another fact, also important it may be, must be remembered. The volume of aerated water that flows down from above tide-water in the former season, is *far less* than at other seasons. There are no means of exactly determining the difference at present at hand, except by comparison with other rivers in nearly the same latitude. The difference, for instance, between the maximum flow of the Hudson at Albany in March, and its minimum in July, is as *seven to one!* If this rule holds as to the Passaic, the amount of oxygen brought down by the stream, to attack and destroy the fæcal and urinary compounds cast into the river at Newark, is in July but one-fourteenth as great as during the flooded seasons. This, however, is doubtless too strong a view, as the alternate sweep of the stream up and down at each tidal change, even to some extent as far up as the Dundee dam, some seven miles above Belleville,* must assist largely in the aerating operation, and this operation is therefore by no means wholly dependent on the down-flow of the river itself. Still, when we consider that in midsummer the heat intensifies putrefaction, and that the amount of available oxygen to destroy its products is largely diminished by the enfeebled solubility of oxygen in the water, it would appear that we have a reasonable solution of the unpleasant odor and taste that the water has of late years sometimes acquired in July.†

Moreover, looking to the future, though there seems every reason, on considering these analyses, to believe that no detriment to the public health has *up to this time* arisen from the use of these waters, there seems to be no good reason to deduce the slightest confidence or belief in an indefinite, or even a long continuation of this immunity. Newark grows rapidly, and grows towards Belleville; and the distance from your pumps within which it is safe to have a common sewer emptying into your river has not yet been determined.

Remarks upon Aeration of Potable Waters.—It will probably not be expected that space should be occupied with authorities, quoted in support of the proposition, that a necessary condition of a healthy

* I was informed at Belleville that the tides there average 5 and 12 feet, and are three-quarters of an hour later than at New York. H. W.

† I was told by a leading butcher of Hoboken, a reliable man, that he did not dare to use the hydrant water in the summer season to wash his meat, as it quickly turned the latter green; a fact which did not hold when well water was used. H. W.

water is good aeration. The universal experience of mankind has taught them this. A well or an underground cistern may be deprived of light (indeed the less light the better), but *air* it must have, or it putrefies in spite of all.

Dr. Letheby has recently produced facts to show that the death-rates of British towns are proportional to the absence of the earthy bases from the water supply; and has argued that these bases are needed for the making of blood, bones, etc. His facts are undeniable, but the present writer has a very different explanation to suggest, namely, that these bases are needed by oxygen in its work of nitrification and destruction of putrefactive matter, an explanation which seems far more satisfactory.

Early in this investigation, when your reporter first began to see the nature of the process going on in the Passaic waters, the immediate necessity forced itself upon him of possessing reliable methods of determining the amount and rate of aeration of water. On trying the methods heretofore in use, they were found far from reliable or delicate enough for the purposes required. He therefore cast about him for new means, and in the course of time and experiment settled upon a reagent introduced long since by Liebig, for determining oxygen in the air, and widely used in gas analysis, called *pyrogallic acid*. (As it is not an acid, it is preferable to follow some of the English chemists, and call it *pyrogalline*.) The details of the methods that have been founded on the use of this agent in water analysis must be reserved for communication to the chemical world in another form. Great difficulties were met with in the practical application, but have been satisfactorily overcome. It furnishes now the means not only of determining the amount of oxygen already existing in the water, but also of determining the rate of its absorption by different waters, and under different circumstances.

Considerations in reference to new sources of water supply, or new modes of supply, are not within the province of this Report; but it may be considered as pertinent for your reporter to submit to your Board any views looking towards improvements of, and making the best of, the present supply and mode of supply; premising, however, with emphasis, that these are only intended to be regarded as *suggestions*, which, by awakening attention to the subject, may possibly give rise to far better and more practicable plans.

Now, that we are acquainted with the nature of the wonderful process of regeneration and revivification that goes on in our water, it

behooves us, in fact, if within our power, to promote it; to assist nature, and to study the means of doing so, without delay. What conditions, then, should we supply to the water, in order to promote this process? Evidently two, oxygen and time; or, as it may be better to express it, opportunity to absorb oxygen, and time for the oxygen to do its work.

One suggestion to be thrown out here amounts simply to this: that, if means were adopted to keep the water in one of your reservoirs in a condition of gentle agitation, or rather intestinal motion, in every part, so as continually to turn up new surfaces to the air, the absorption of oxygen would be enormously promoted. To support this assertion, it may be stated that by the new method, the water taken from the receiving reservoir on the tenth of October last, was found, when standing *at rest*, at 60°, to absorb oxygen from the air in 12 hours to the depth of 4·75 inches, and in 24 hours to the depth of but 7·5 inches. After this, the absorption became very slow, and in two days almost imperceptible. The motive power for keeping the reservoir water in motion would be trifling, and readily obtainable from the inflowing water.

The immediate objection made will be that one function of the reservoirs is to cause the water to *settle* and deposit its sediment; and that motion will interfere with this. This is by no means certain, as it is very probable, from the analytical results presented in this report, that little or no settling is actually accomplished, in your distributing reservoir at least. The water from the receiving reservoir of October 10th, gave 0·479 of sediment, while that from the hydrant in Hoboken of November 1, gave 0·493. The latter result agrees also with that of Professor Chandler, who found, in hydrant water of May 3d, 0·520 of sediment. One reservoir might, at present, be sufficient for settling purposes.

The applicability of this idea would of course be greatest during those seasons when the reservoirs, lying in hot still sunshine for whole days together, are obviously in the condition, more than any other, of stagnating pools, in whose bosom all kinds of organic changes, including putrefaction (in the absence of abundant oxygen), as well as germination, may well be believed to find most favorable conditions.

Still another suggestion, also of a very simple character, which ought to have considerable efficiency for a time, is to remove, not your pumping works, but the point from which you take the water from the river, some miles further away from Newark, leading it of course to the works by a canal.

*The Passaic Water-Shed.**—Not being able to find any data for the computation of the flow of the Passaic River, it was determined to make a careful measurement of its water-shed or basin, which was accomplished by the method of weighing.

Three sections of the large geological map of the State were found, on being pieced together carefully, to cover all but a very trifling corner of the water-shed, at the head-waters of the Saddle River. The wonderfully tortuous rim of the basin was now very carefully traced out all round, following a medial line between the heads of the small tributaries and those of the adjoining basins, using a soft pencil. Tracing muslin of the best quality was now superposed, and the former line followed round again. Small sharp scissors were now called into requisition, the water-shed cut out, carefully rolled up, and weighed on a delicate chemical balance. 120 square inches of the same muslin were then carefully measured out, cut out in the same way and also weighed. As the scale of the map is two miles to the inch, this represents 480 square miles. The weight of this and of the whole water-shed being known, it becomes a simple rule-of-three sum.

Two such maps were made. One, on which I endeavored roughly to trace out the river and its main tributaries, I present herewith, that you may be enabled to inspect the form of this singular basin. On the other were traced out, before detaching it, the boundaries of the different geological formations that are included within the basin, also the State line between New Jersey and New York. This latter map was dissected, and weighed piecemeal, to determine these different areas.

The following are the figures obtained:

Area of Passaic Water-Shed, . . .	908	sq. miles.
Area of the New York portion thereof, . .	148·5	"
Area of the Crystalline Rocks of the Highlands, within the Water-Shed, ...	484·5	"
Area of the Brown "Sandstone," and Trap (Triassic) formations, ...	423·5	"

[It was the original intention to enter into some geological, or rather lithological discussion, based on these measurements, and the bearing of the results of the analyses upon the composition of the rocks, the more especially as your reporter has spent much of his life

* A chapter containing a discussion of former examinations of Passaic water is omitted in this abstract.—Ed.

in the study of the rocks, minerals and general geology of northern New Jersey. It was intended to calculate the rainfall in the basin for each month in the year, and other interesting matters besides; but it is now feared that the necessary limits of this report would be surpassed.]

The water-shed of the Passaic, it thus appears, is much larger than had been anticipated, and it is evident that the estimates heretofore accepted, of the average flow of this stream, are greatly below the truth. The annual rainfall is known to be more than 50 inches,* and a simple calculation shows, therefore, that the total amount of water received by the Passaic and its tributaries in one year, is 782,100,000,000 gallons, or 2,115,000,000 gallons per day, on an average. As it is usual to allow a loss of one-half, however, by evaporation, it will be safe to call the average daily flow of the Passaic one thousand million gallons. This is not much less than the average assigned to the river Thames, 1,350,000,000 gallons; although that river is more than 250 miles long and ours but 80 miles. This fact serves to illustrate the very remarkable character of the Passaic basin. The rainfall, however, in the Thames valley is but 27 inches. The Croton water-shed measures 339 square miles, so that our water-shed is 2·7 times the size of that which supplies New York City. Nine-tenths of this water-shed lies above Paterson, and its drainage flows over the falls at that place. We have water enough (with reservoirs of sufficient capacity and in proper locations) for all our cities for centuries to come, not only for domestic, steam and manufacturing uses, but even for water-power, where small powers are required (as for sewing-machines, for example). The problem is, how to make it come to our cities without constantly augmenting cost. This, however, is a matter outside the scope of the present report.

The Sewage of Paterson.—Included in the instructions upon which this investigation was based, were examinations into the question that has caused alarm to some, whether the Passaic water is not possibly contaminated, and rendered poisonous, discharged from the dye-works, and other works in which chemicals are employed, in Paterson.

* The mean annual rainfalls were, for a series of years:

For Newark,	50·2
For Paterson,	51·2
For Dover,	50·1
Mean,	50·5

It is among chemists an accepted fact, that no such substances are thrown by manufacturing cities into rivers, in any *permanent* form of solution; but, as many who use our water would be much better satisfied with direct chemical evidence on this head, as much time was spent in these examinations as could be reasonably taken from things of greater profit, visits were made to a number of these works, and it was ascertained that there was a possibility of small quantities of waste lead and copper solutions finding their way into the drains. The aniline colors, some of which, it has been suggested, might carry *arsenic* into the river, were stated to be too costly to allow of any waste. They are always used up entirely. It has been stated on a previous page that samples were taken from two of the main sewers, and from the river below all the sewers at the Straight Street Bridge. All these, though kept in a room without fire, tightly stoppered, and in very cold weather, began straightway to putrefy, and to evolve free sulphuretted hydrogen. As neither lead, copper nor arsenic can remain in solution for a moment in water containing sulphuretted hydrogen, this was pretty conclusive; yet it was deemed best to make a crucial experiment. To a portion of each water was *added* small quantities of solutions of lead, copper and arsenic. After settling for twenty-four hours, the filtered liquids were rigidly tested, and no trace of either of these three metals could be found left in solution.

It should be added, for the behoof of chemists, that all these samples were absolutely neutral to test papers; a somewhat surprising fact, when it is stated that the samples were collected on a *washing day* (Tuesday, from 2·30 to 3·30 P. M.), and it was expected that they would be perceptibly affected by the alkali of the soap. The amount of sediments deposited by these samples respectively, after standing at rest one month, were as follows:

WATER.	Quantity employed.	Grains of dry Sediment per U.S. gallon.
River, from Straight St. bridge,	530 grammes.	1·101
Prospect Street sewer, . .	578 "	2·119
Paterson Street sewer, . .	680 "	10·194

It had been intended to report other analytical results obtained in connection with the sewers, but as the above comprise all that have any *obvious* sanitary bearing, it is judged better not to swell the report with them.

Some microscopic observations were made on the above sediments, but nothing observed of much interest, except the somewhat curious fact that the river water taken from the Straight Street Bridge gave a sediment singularly crowded with fragments of *fibres* of various kinds, derived apparently from different textile tissues.

Summary.—1. The basin drained by the Passaic River contains over 900 square miles of territory, and receives annually over 782,000,000,000, or, as daily average, over 2,100,000,000 of gallons of water.

2. Allowing an average loss of one-half by evaporation (doubtless an over-estimate), the annual flow of the river at Newark is 390,000,000,000 gallons.

3. The actual daily flow varies within wide limits, as yet undetermined, possibly between 200,000,000 to 300,000,000 per day during the dryest summers, and 2,000,000,000 or 3,000,000,000 or more during times of flood.

4. The daily flow, with the river at an average height, may be called 1,000,000,000 gallons; more than nine-tenths of which, say 900,000,000, must flow over the Falls of Paterson. The whole discharge of this river is 2·7 times that of the Croton River, which supplies New York.

5. The water belongs naturally to the class known as "peaty" waters, though not largely imbued with this contamination, at least, in the lower part of its course.

6. From the Falls down to the mouth, the peaty matter gradually diminishes in amount.

7. The water is alkaline in character, or at least has a considerable excess of basic over acid constituents. The amounts of lime and magnesia vary at times, but do not differ much from the average of the Croton water.

8. In the lower part of its course, at least, the river contains in solution quantities of *nitrates*, sufficient to be easily and accurately determined by delicate chemical analysis.

9. These nitrates are increased in quantity by flowing through the city of Paterson, and again nearly doubled by flowing through Newark.

10. These (or their nitric acid) are derived from the oxidation of the animal excretions and other similar refuse that pass into the river at Newark, Paterson and elsewhere, from sewers, slaughter-houses and other sources; materials that would otherwise remain in the water in a state of putrefaction.

11. There is no reason to believe that these nitrates affect health in any way whatever.

12. The oxidizing power of this alkaline river water, in the *autumn* season, is so great, that but slight traces of the sewer-matter can be detected, after flowing but four miles through the channel; so little being left that the water acquires no odor on being kept in a closed bottle at 60° F. for one month.

13. There are as yet no results on record in the way of tests during the *summer* season, when the water absorbs much less oxygen.

14. This water allows the germination, and supports the growth, of green confervoid vegetation in its bosom, under favorable circumstances, until after it has passed through the city of Newark, when it *loses this power;* losing some of its constituents at the same time, while gaining others, and changing materially in composition.

15. In the opinion of the undersigned, it will not be safe to have sewers from the city of Newark, *at any season*, discharge into the river nearer to the pumping works than they do at present; unless the water is conducted to the pumps from a point correspondingly further up the river.

16. This latter precaution is suggested for adoption at once, so long as the present pumping stations are adhered to.

17. It is suggested also that the practicability be examined into, by the Engineer of your Board, of keeping the water, in at least one of the reservoirs, during the summer months at least, in a condition of slow intestinal motion or agitation, in order to promote absorption of oxygen, and consequent destruction of organic impurities.

18. No metallic or mineral poison can be detected, as cast into the stream at Paterson; nor could any such remain in solution therein for any length of time.

All of which is respectfully submitted.

The St. Gothard Tunnel.—The total extent of advance in this undertaking, at the end of March last, was 806·4 feet. About 800 workmen are employed. Considerable trouble is at present being suffered on account of the flow of water into the workings through the micaceous rock, which at one time amounted to seventy-five quarts per second, and greatly delayed the progress of the work.